Reference 5

B&V WASTE SCIENCE AND TECHNOLOGY CORP.

MEMORANDUM

Chevron Chemical Company

BVWST Project 52013.040
BVWST File E.1
May 28, 1992

Source Area Calculations
Hazardous Waste Quantity Calculations

To: Project File

From: Cynthia Gurley CG.

Hazardous waste quantity was estimated for source: 3 at Chevron Chemical Company in Orlando, Florida. The area of contaminated soil (Source: 3) is based on surface soil sample locations and Figure 3-4 site sample location map produced by Brown and Caldwell Consultants in the Contamination Assessment Report (December 1990). The volume of sources 1 and 2 were estimated based on measurements made while in the field. These dimensions are reported in the Contamination Assessment Report conducted in December 1990 (Ref. 3, p. 1-4, Table 4-4).

Waste quantity calculations for each of the source areas are provided in the attached.

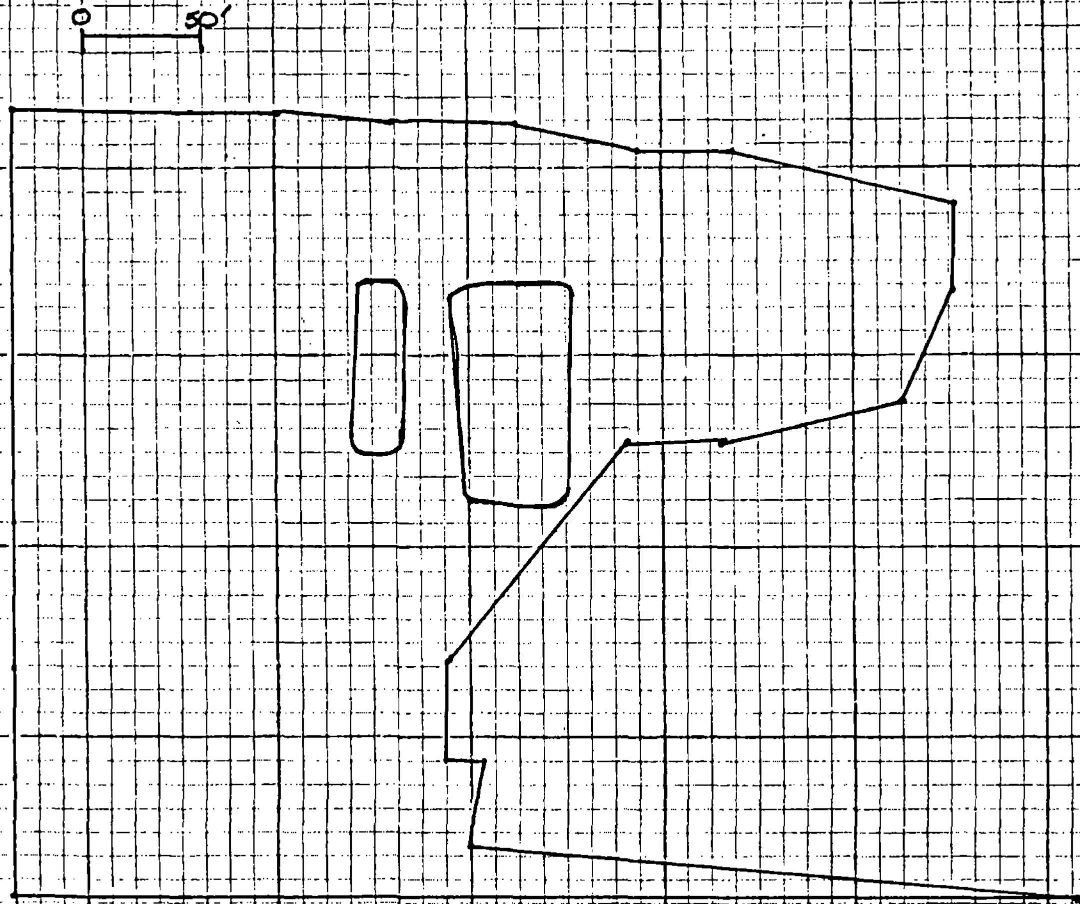
10826500

BLACK & VEATCH
ENGINEERS-ARCHITECTS

Owner Source Area Calculation
Plant Contaminated soil Unit
Project No. File No.
Title Source: 3

Computed By Cynthia K. Gurley
Date 4-15-92 19
Checked By
Date 19
Page of

50 ft ÷ 5 blocks = 10 ft/block side
1 block = 100 ft²



Source: 3

866 blocks

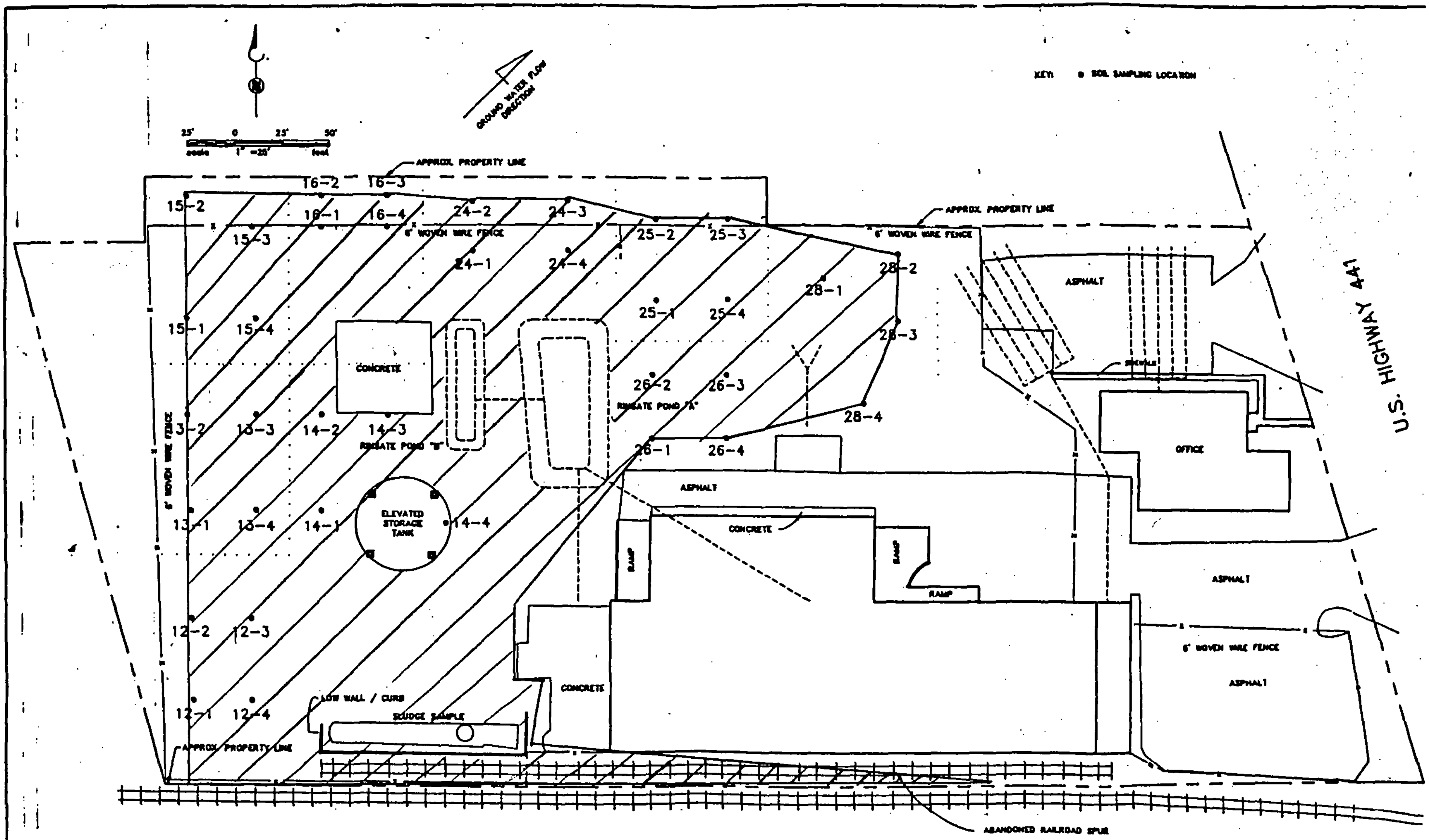
$\left(866 \text{ blocks}\right)\left(\frac{100 \text{ ft}^2}{1 \text{ block}}\right) =$

$= 86600 \text{ ft}^2$

Generated by Cynthia K. Gurley
B+V Waste Science and Technology Corp. (1992)

... AND YOUR CALCULATIONS MUST BE CLEARLY IDENTIFIED, INITIALED.

DO NOT WRITE IN THIS SPACE



Brown and Caldwell Consultants

= Area of Contaminated Soil.

Figure 3-4. Soil Sampling Locations on Northern and Western Portions of the Site

B&V WASTE SCIENCE AND TECHNOLOGY CORP.

Hazardous Waste Quantity Calculations

1. Rinsate Pond A - Surface Volume: $90' \times 45' \times 3' = 12{,}150\ ft^3$
   Source type: surface impoundment

   Assigned: $12{,}150\ ft^3 \times 3.704 \times 10^{-2}\ yd^3/ft^3 = 450.04\ yd^3$
   $450.04\ yd^3 \div 2.5 = 180.01$

2. Rinsate Pond B - Surface Volume: $70' \times 20' \times 3' = 4{,}200\ ft^3$
   Source type: surface impoundment

   Assigned: $4{,}200\ ft^3 \times 3.704 \times 10^{-2}\ yd^3/ft^3 = 155.57\ yd^3$
   $155.57\ yd^3 \div 2.5 = 62.23$

3. Contaminated Soil - Surface Area: $86{,}600\ ft^2$
   Source type: Landfill

   Assigned: $86{,}600\ ft^2 \div 34{,}000 = 2.55$

Waste Quantity Factor Total

1.	Rinsate Pond A	180.01
2.	Rinsate Pond B	62.23
3.	Contaminated Soil	2.55
		244.79

(Reference 1, Table 2-6,p. 51591) : 100

STATE OF FLORIDA
STATE BOARD OF CONSERVATION

DIVISION OF GEOLOGY
Robert O. Vernon, Director

REPORT OF INVESTIGATIONS NO. 50

WATER RESOURCES OF ORANGE COUNTY, FLORIDA

By
W. F. Lichtler, Warren Anderson, and B. F. Joyner
U. S. Geological Survey

Prepared by the
UNITED STATES GEOLOGICAL SURVEY
in cooperation with the
DIVISION OF GEOLOGY, FLORIDA BOARD OF CONSERVATION
and the
BOARD OF COUNTY COMMISSIONERS OF ORANGE COUNTY

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1968

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CONTENTS

TABLE

Aerial view of the Orlando business district looking northward from Lake Lucerne.

WATER RESOURCES OF ORANGE COUNTY, FLORIDA

By

W. F. Lichtler, Warren Anderson, and B. F. Joyner

ABSTRACT

The population and industry of Orange County are expanding rapidly but the demand for water is expanding even more rapidly. This report provides information for use in the development and management of the water resources of the area.

The county is divided into three topographic regions: (1) lowlying areas below 35 feet (2) intermediate areas betweeen 35 and 105 feet and (3) highlands above 105 feet. The highlands are characterized by numerous sinkholes, lakes and depressions.

Surface runoff forms the principal drainage in the lowlying and intermediate regions, whereas underground drainage prevails in the highlands.

Lakes are the most reliable source of surface water as swamps and most of the streams, except the St. Johns and Wekiva Rivers, go dry or nearly dry during droughts.

Approximately 90 of the 1,003 square miles in Orange County are covered by water. The southwestern 340 square miles of the county drain to the south to the Kissimmee River. The remainder drain to the north to the St. Johns River.

The water in the lakes and streams in Orange County generally is soft, low in mineral content, and high in color. The quality of the water in most of the lakes remains fairly constant except wnere pollution enters the lakes.

Ground water is obtained from: (1) a nonartesian aquifer composed of clastic materials of late Miocene to Recent age; (2) several discontinuous shallow artesian aquifers in the Hawthorn Formation of middle Miocene age; and (3) the Floridan aquifer composed of limestone of Eocene age.

The surficial nonartesian aquifer yields relatively small quantities of soft water that is sometimes high in color. The shallow artesian aquifers yield medium quantities of generally moderately hard to hard water. The Floridan aquifer is the principal source

of ground water in Orange County. It comprises more than 1,300 feet of porous limestone and dolomite and underlies sand and clay deposits that range in thickness from about 40 to more than 350 feet. Most large diameter wells in the Floridan aquifer will yield more than 4,000 gpm (gallons per minute).

Water levels of the Floridan aquifer range from about 15 feet above to more than 60 feet below the land surface. The quality of the water ranges from moderately hard in the western and central parts to saline in the extreme eastern part of the country.

The Floridan aquifer in Orange County is recharged by rain mostly in the western part of the county. Drainage wells artificially recharge the Floridan aquifer, but may pollute the aquifer unless the quality of the water entering the wells is carefully controlled. Urbanization in the recharge area and pollution can reduce the amount of potable water available in the Floridan aquifer. Artificial injection of good quality surplus surface water can increase the amount of water available and improve its quality, especially in the eastern part of the county where there is salty water in the aquifer.

Use of ground water in 1963 was estimated to average about 60 mgd (million gallons per day) for municipal, industrial, domestic and irrigational use. Use of surface water was estimated to be about 5.5 mgd for irrigation. Surface water was also used for cooling and recreation.

INTRODUCTION

The rapid increase of population and industry in Orange County and nearby areas has created a more than commensurate increase in the demand for water. Not only are there more people and more uses for water, but the per capita use of water is increasing. East-central Florida, as a growing center in missile development and space exploration, is increasing in population and industry; therefore, the increase in demand for water is expected to continue and even to accelerate.

This report contains information on the quantity, chemical quality, and availability of water in Orange County. The report will be useful to people who have the responsibility of planning, developing, and using the water resources of Orange County and much of the East-central Florida region and to anyone interested in water.

PURPOSE AND SCOPE OF INVESTIGATION

The purpose of this investigation is to furnish data that will be useful in the conservation, development, and management of the water resources of Orange County. Water is one of the most important natural resources and Orange County, with more than 50 inches of annual rainfall, hundreds of lakes, and the Floridan aquifer, is blessed with an abundant supply. However, the rainfall is not evenly distributed throughout the year, or from year to year, nor are there adequate storage reservoirs in all parts of the county.

Knowledge of all factors affecting the water resources of an area is necessary in planning for the protection, efficient development, and management of water supplies. Recognizing this need, the Board of County Commissioners of Orange County entered into a cooperative agreement with the U. S. Geological Survey to investigate the water resources of Orange County. The investigation is a joint effort by the three disciplines within the Water Resources Division of the Survey under the direction of W. F. Lichtler, project leader. The report was prepared under the supervision of C. S. Conover, District Chief, Water Resources Division, Tallahassee. It is the comprehensive report of the 5-year investigation and also incorporates information contained in an interim report (Lichtler, Anderson, and Joyner, 1964), a lake-level control report (Anderson, Lichtler, and Joyner, 1965), a groundwater availability map (Lichtler and Joyner, 1966), and a surface-water availability map (Anderson and Joyner, 1966), produced as byproduct reports of the investigation.

The report includes determinations of variation in lake levels, stream flow, chemical quality of surface and ground waters and ground-water levels, evaluation of stream-basin characteristics, delineation of recharge and discharge areas, investigation of characteristics of the water-bearing formations, assembly of water-use information and interpretations of water data.

ACKNOWLEDGMENTS

The authors express their appreciation to the many residents of Orange County who freely gave information about their wells and to various public officials, particularly the Board of County Commissioners, whose cooperation greatly aided the investigation.

Special appreciation is expressed to Fred Dewitt, County Engineer; to Robert Simon and Jesse Burkett of the City of Orlando Water and Sewer Department; and to L. L. Garrett and Gene Birdyshaw of the Orlando Utilities Commission for their assistance.

Appreciation is given to the well drillers in and near Orange County who furnished geologic and hydrologic data and permitted collection of water samples and rock cuttings and measurements of water levels during drilling operations, and to the grove owners, managers and caretakers who furnished data on irrigational use of water.

The Board of Supervisors of the Orange Soil Conservation District and Albert R. Swartz and other members of the technical staff of the U. S. Soil Conservation Service gave much useful advice and information and provided strong support and encouragement during the course of the investigation.

PREVIOUS INVESTIGATIONS

Two previous investigations of the water resources of Orange County have been made. A report by the U. S. Geological Survey (1943) gives the results of a study of lakes as a source of municipal water supply for Orlando. A detailed investigation by Unklesbay (1944) deals primarily with drainage and sanitary wells in Orlando and vicinity and their effect on the ground-water resources of the area.

Other, investigators have included Orange County in geologic and hydrologic studies. Fenneman (1938), Cooke (1939), MacNeil (1950), and White (1958) describe the topographic and geomorphic features of Central Florida. Cole (1941, 1945), Cooke (1945), Vernon (1951), and Puri (1953) describe the general geology of Central Florida and make many references to Orange County. Sellards (1908), Sellards and Gunter (1913), Matson and Sanford (1913), Gunter and Ponton (1931), Parker, Ferguson, Love, and others (1955), D. W. Brown, Kenner, and Eugene Brown (1957), and D. W. Brown and others (1962) discuss the geology and water resources of Brevard County. Stringfield (1935, 1956) and Stringfield and Cooper (1950) investigated the artesian water in peninsular Florida, including Orange County. Collins and Howard (1928), Black and Brown (1951), Wander and Reitz (1951), and the Florida State Board of Health (1961) give information about the chemical quality of water in Orange County.

WELL-NUMBERING SYSTEM

The well-numbering system used in this report is based on latitude and longitude coordinates derived from a statewide grid of 1-minute parallels of latitude and meridians of longitude. Wells within these quadrangles have been assigned numbers consisting of the last digit of the degree and the two digits of the minute of the line of latitude on the southside of the quadrangle, the last digit of the degree and the two digits of the minute of the line of longitude on the east side of the quadrangle, and the numerical order in which the well within the quadrangle was inventoried. For example, well 827-131-3 is the third well that was inventoried in the 1-minute quadrangle north of 28°27' north latitude and west of 81°31' west longitude (See figure 1.).

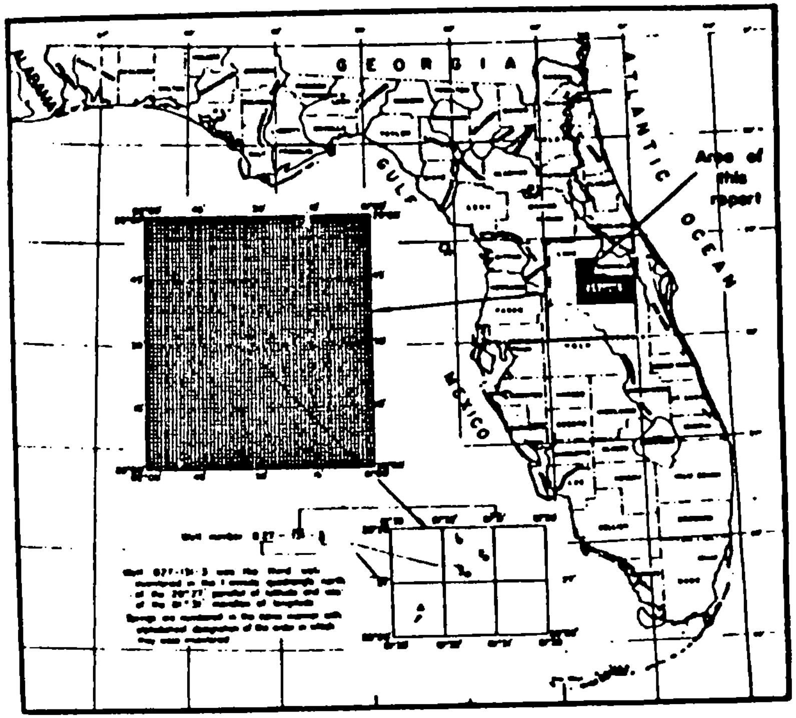

Figure 1. Location of Orange County and illustration of well-numbering system.

Wells referred to by number in the text can be located on figure 2 by this system.

DESCRIPTION OF THE AREA

LOCATION AND EXTENT

Orange County is in the east-central part of the Florida peninsula (fig. 1). It has an area of 1,003 square miles of which about 916 square miles are land and about 87 square miles are water. It is bounded on the east by Brevard County, on the north by Seminole and Lake Counties, on the west by Lake County, and on the south by Osceola County.

The estimated population of Orange County in 1963 was 290,000. In that year, the estimated population of Orlando, the largest city in the county, was 90,000 while Winter Park, the second largest city, had an estimated population of 20,000. The growth rate of Orange County's population has increased enormously since 1950 (See figure 63) and this trend is expected to continue. The population of Orange County is expected to reach 530,000 by 1975.

The principal agricultural products in Orange County are citrus, ornamental plants, vegetables, cattle, and poultry. In 1960 there were about 67,000 acres of citrus groves, more than 600 nurseries and stock dealers, about 6,000 acres of vegetables—mostly in the Zellwood muck lands northeast of Lake Apopka—about 23,000 head of cattle and about 180,000 laying hens in the county.

TOPOGRAPHY

Orange County is in the Atlantic Coastal Plain physiographic province described by Meinzer (1923, pl. 28). The county is subdivided into three topographic regions: (1) the lowlying regions where altitudes are generally less than 35 feet; (2) intermediate regions where altitudes are generally between 35 and 105 feet; and (3) highland regions where altitudes are generally above 105 feet. (fig. 3).

The lowland regions include the St. Johns River marsh, the northern part of the Econlockhatchee River basin and the northeastern part of the county east of Rock Springs. Altitudes range from about 5 feet above msl (mean sea level) near the St. Johns River to about 35 feet above msl where there is a relatively steep scarp in many places in Orange County. The St. Johns River marsh

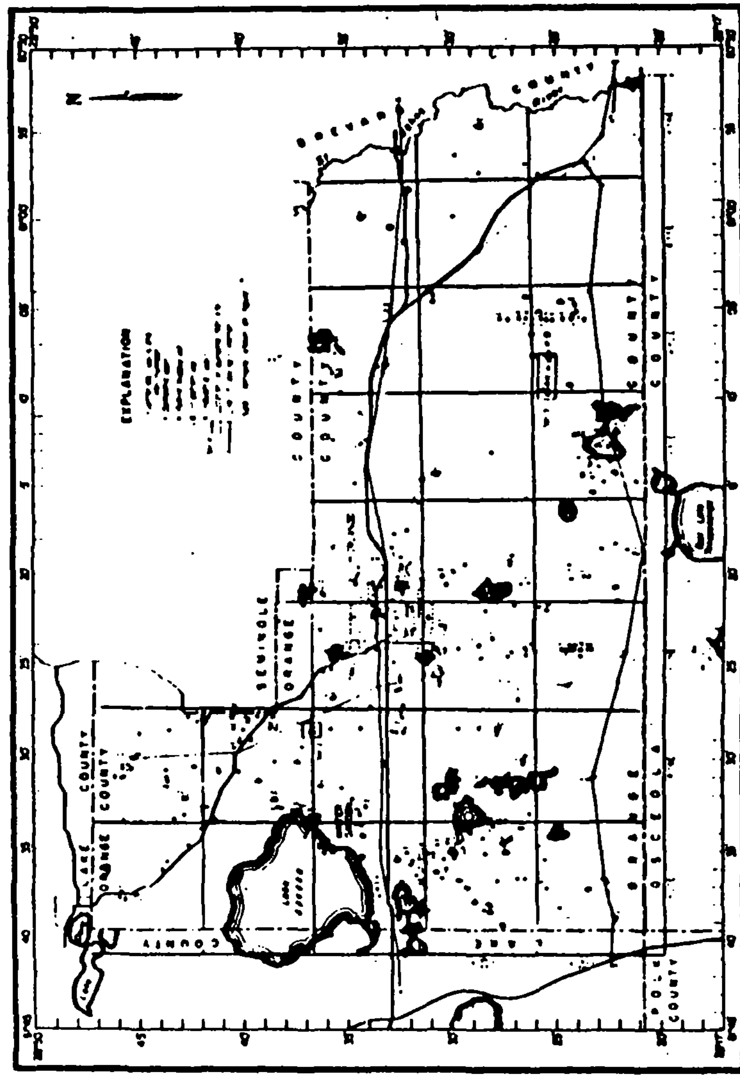

Figure 2. Location of inventoried wells other than drainage wells, Orange County, Florida.

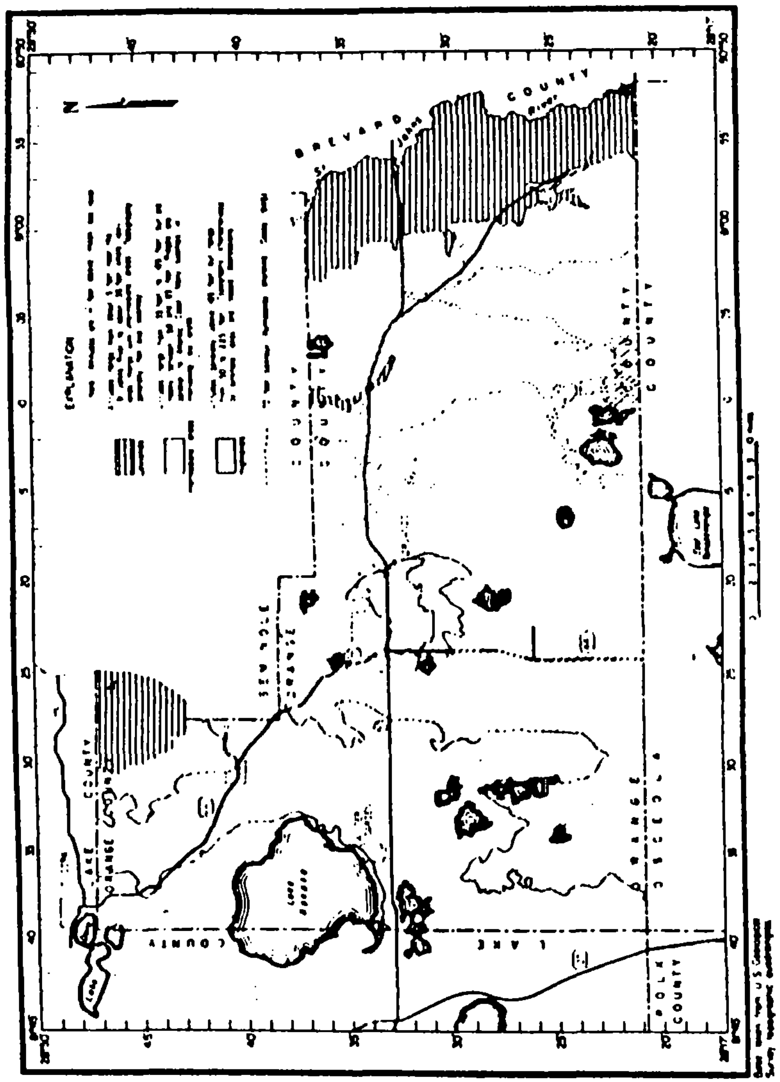

Figure 3. Topographic regions of Orange County, Florida.

in the eastern part of the county, is a part of Puri and Vernon's (1964, figure 6) Eastern Valley. The low area east of Rock Springs is a part of the Wekiva Plain and the Econlockhatchee Valley is a small part of the Osceola Plain.

The intermediate region occupies most of the middle part of the county between the lowlands and the highlands. Altitudes range from 35 to 105 feet above msl but are mostly between 50 and 85 feet above msl. A characteristic area of ridges and intervening lower areas parallel the Atlantic coast is best developed in the area between Orlando and the Econlockhatchee River. These ridges are believed to be fossil beach ridges from higher stands of the sea. The intermediate region coincides, in general, with Puri and Vernon's (1964, figure 6) Osceola Plain except for the area in the northwestern part of the county which is a part of Puri and Vernon's Central Valley.

The highlands occupy the western part of Orange County with an island outlier in Orlando and vicinity. Altitudes are generally above 105 feet but range from about 50 feet in low spots, such as the Wekiva River basin, to about 225 feet above msl near Lake Avalon on the western border of the county. The highlands contain many lakes and depressions, most of which do not have surface outlets.

The highland regions in Orange County include parts of Puri and Vernon's Orlando Ridge, Mount Dora Ridge, and Lake Wales Ridge.

The three topographic regions described above are approximately equivalent to the Pleistocene terraces postulated by MacNeil (1950) as the Pamlico terrace from about 8 feet to about 30 feet above msl, the Wicomico terrace from about 30 feet to about 100 feet above msl, and the Okefenokee terrace from about 100 to 150 feet above msl.

Cooke (1939, 1945) has called the surface defined by the 42- and 70-foot shorelines the Penholoway terrace and the surface defined by the 70- and 100-foot shorelines the Wicomico terrace. The areas in Orange County that are above 150 feet probably are sandhills or altered remnants of higher terraces.

The water resources of Orange County are directly related to the topography of the area. In general, the highlands are the most effective natural ground-water recharge areas. They have few surface streams but have many lakes and depressions. The intermediate region ranges from good to very poor as a ground-water recharge area. There are many lakes in some areas and none in others. Surface streams in this region either go dry or recede to very low flow after relatively short periods of drought. The lowlands are ground-water discharge areas and contain few lakes except in the mainstem of the St. Johns River. Streamflow is more sustained than in the other regions because of water stored in the lakes along the mainstem of the St. Johns River, spring flow, and seepage of ground water from both the water-table and artesian aquifers.

CLIMATE

Orange County has a subtropical climate with only two pronounced seasons—winter and summer. The average annual temperature at Orlando is 71.5°F and the average annual rainfall is 51.4 inches. (See table 1.) Summer thunderstorms account for most of the rainfall. Thunderstorms occur on an average of 83 days per year, one of the highest incidences of thunderstorms in the United States (U. S. Weather Bureau, Annual Report 1960).

SINKHOLES

Sinkholes are common in areas such as Orange County that are underlain by limestone formations. Rainfall combines with carbon dioxide from the atmosphere and from decaying vegetation to form weak carbonic acid. As the water percolates through the limestone, solution takes place and cavities of irregular shape are gradually formed. When solution weakens the roof of a cavern to the extent that part of it can no longer support the sandy overburden, sand falls into the cavity and a sinkhole forms on the surface. (See figure 4.) Most of Orange County's natural lakes, ponds, and closed depressions probably were formed in this manner. Sinkholes range in size from small pits a few feet in diameter to large depressions several square miles in area. Large depressions are usually formed by the coalescence of several sinkholes.

Sinkholes may form either by sudden collapse of a large part of the roof of a large cavern or by gradual infiltration of sand through small openings in the roof of the cavity. The latter condition is illustrated by the formation of a sinkhole in Canton Street in Winter Park in April 1961. The sink was first noted as a depression in the graded road. By the following day a hole about 6 feet in diameter had formed. In the next 2 days the hole gradually

TABLE 1. TEMPERATURE AND RAINFALL AT ORLANDO, FLORIDA

	Normal daily maximum temperature[1,3]	Normal daily minimum temperature[2]	Normal average temperature[1,3]	Normal rainfall inches[1,3]	Maximum rainfall[3]		Minimum rainfall[3]	
					Inches	Year	Inches	Year
January	70.7	50.0	60.4	2.00	6.44	1948	0.15	1950
February	72.0	50.7	61.4	2.42	5.64	1960	0.10	1944
March	75.7	54.0	64.9	3.41	10.54	1960	0.16	1956
April	80.5	59.8	70.2	3.42	6.18	1953	0.28	1961
May	85.9	66.2	76.1	3.57	8.58	1957	0.43	1961
June	89.1	71.4	80.3	6.96	13.70	1945	1.97	1948
July	89.9	72.0	81.5	8.00	19.57	1960	3.83	1963
August	90.0	72.5	81.8	6.94	15.19	1953	3.20	1960
September	87.6	72.4	80.0	7.23	15.87	1945	1.65	1958
October	82.6	65.3	74.0	3.96	14.51	1950	0.46	1963
November	75.6	56.2	65.9	1.57	6.39	1963	0.09	1950
December	71.6	51.2	61.4	1.39	4.30	1950	Trace	1944
Yearly	80.9	62.0	71.5	51.37	68.74	1960	39.61	1943

[1]Average for 10 or more years.
[2]U. S. Weather Bureau records, 1931-60.
[3]U. S. Weather Bureau records, 1943-60.

Figure 4. Sinkhole 2 miles west of Orlando formed in summer 1953. It was subsequently filled in and no further sinking has occurred.

increased in size to about 60 feet in diameter and to about 15 feet in depth. The hole was filled and no further development has been noted.

Another sinkhole formed in 1961 in Pine Hills, west of Orlando. A depression about 1-foot deep and 50 feet in diameter that formed on April 23 and 24 was marked only by a faint line in the sand except where the outer edge intersected two houses. The floor of one room, the carport, and the concrete driveway of one house were badly cracked. The corner of the other house dropped about 6 inches. The slow rate of settlement was probably caused by a gradual funneling of the overlying sand and clay into relatively small solution channels in the limestone. The channels eventually became filled and the subsidence ceased.

A sinkhole formed rather rapidly in Lake Sherwood on May 22, 1962. This spectacular sinkhole removed a section of the westbound lane of Highway 50 and about 3,000 cubic yards of fill were required to repair the damage. According to eye witnesses, the sinkhole formed over a period of about 2 hours.

Sinkholes are most likely to form in areas of active ground-water recharge because the dissolving action of the water is greatest when it first enters the limestone aquifer. As the slightly acid water moves through the aquifer, it gradually reacts with the limestone and is neutralized. The prevalence of sinkholes is usually a good indication that the area is, or was in the past, an area of active recharge.

Sinkholes can either improve or impede the recharge efficiency of an area. In some instances, sinkholes breach the semipervious layers that separate the surface sand from the aquifer and permit water to enter the aquifer more readily than before. In other instances, lakes that form in sinkholes become floored with relatively impermeable silt, clay and organic material which retards the downward movement of water.

Much remains to be learned about the solution of limestone by water. Caverns have been discovered several thousand feet below the surface, and evidence indicates that active solution is going on at these depths. Present and future research by the U. S. Geological Survey and other agencies should provide much useful information about this important subject and its relation to ground-water movement and availability.

DRAINAGE

The eastern and southern parts of Orange County are drained principally by surface streams. The St. Johns River and its tributaries drain the eastern and northern part of the county while Shingle Creek, Reedy Creek, Boggy Creek, and canals in the upper Kissimmee River basin drain most of the south-central and southwestern parts of the county. Many swamps and sloughs occur in the eastern and southern parts of the county because of the poorly developed drainage.

Surface drainage in the western and northwestern parts of the county is mostly into closed depressions where it either seeps into the ground or evaporates. A few sinkholes in this area have open connections with solution channels in the underlying limestone. Water that collects in these sinkholes drains directly into the solution channels. Most of the sinkholes, however, are floored with relatively impermeable sediments and the rate of seepage through these lake-filled sinkholes may be less than in areas adjacent to the lakes.

More than 300 drainage wells were drilled between 1906 and 1961 in the upland area of the county, especially in Orlando and vicinity, to drain surface water directly into the artesian aquifer (fig. 5). The greatest activity was during 1960 when about 35 drainage wells were drilled. Considerable quantities of water are drained underground in this manner, but the total amount is not known. The water that enters the aquifer through drainage wells ranges from pure rainwater to water used to flush cow barns.

GEOLOGY

The occurrence, movement, availability, quality, and quantity of the ground water in Orange County are closely related to the geology of the area. Therefore, knowledge of the structure, stratigraphy, and lithology of the geologic formations is essential to an evaluation of the ground-water resources.

Orange County is underlain mostly by marine limestone, dolomite, shale, sand, and anhydrite to about 6,500 feet at which depth granite and other crystalline rock of the basement complex occur. Only the top 1,500 feet of sediments that have been penetrated by water wells will be discussed in this report. A summary of the properties of the formations is given in table 2.

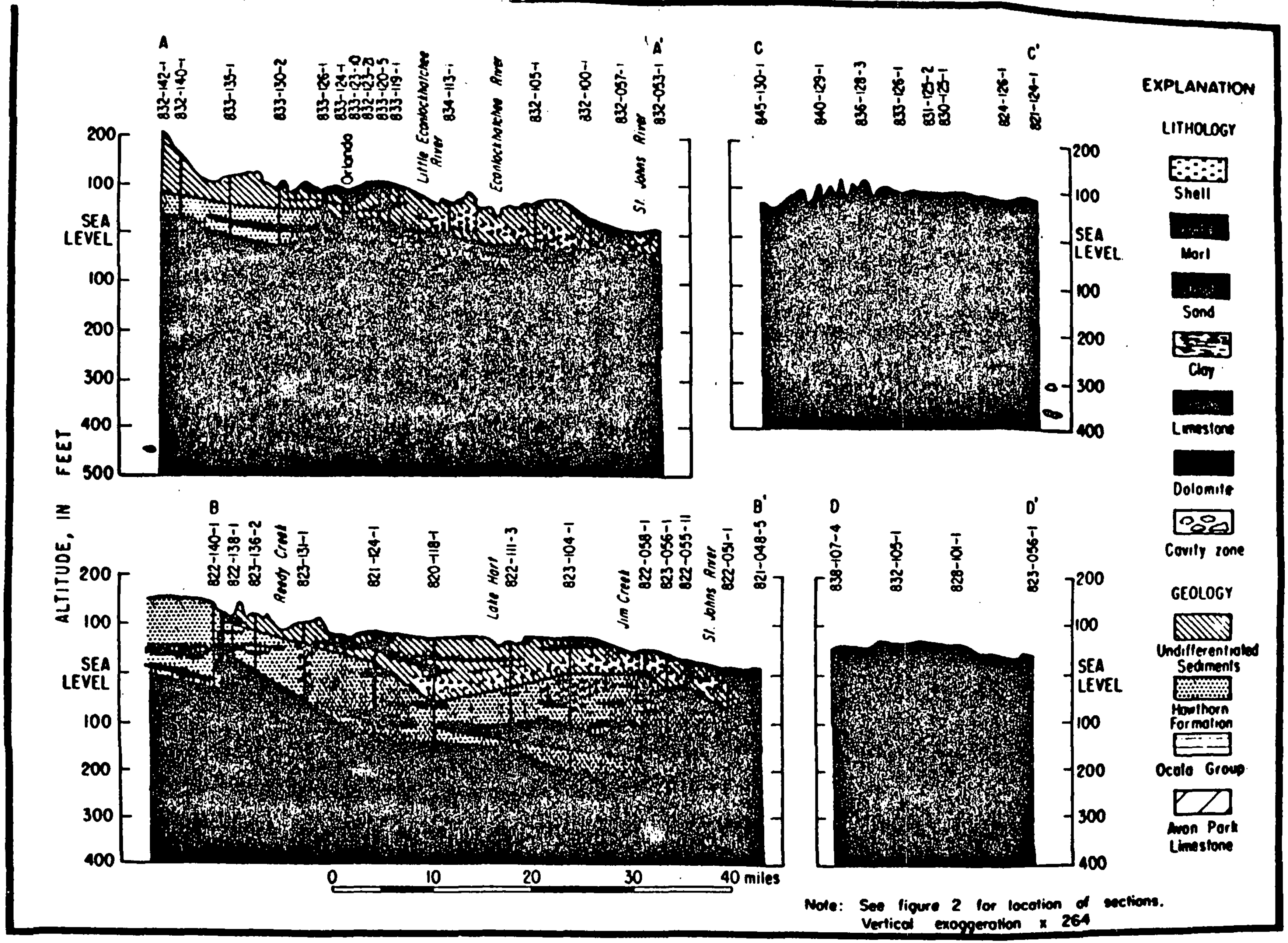

Figure 6. Geologic sections.

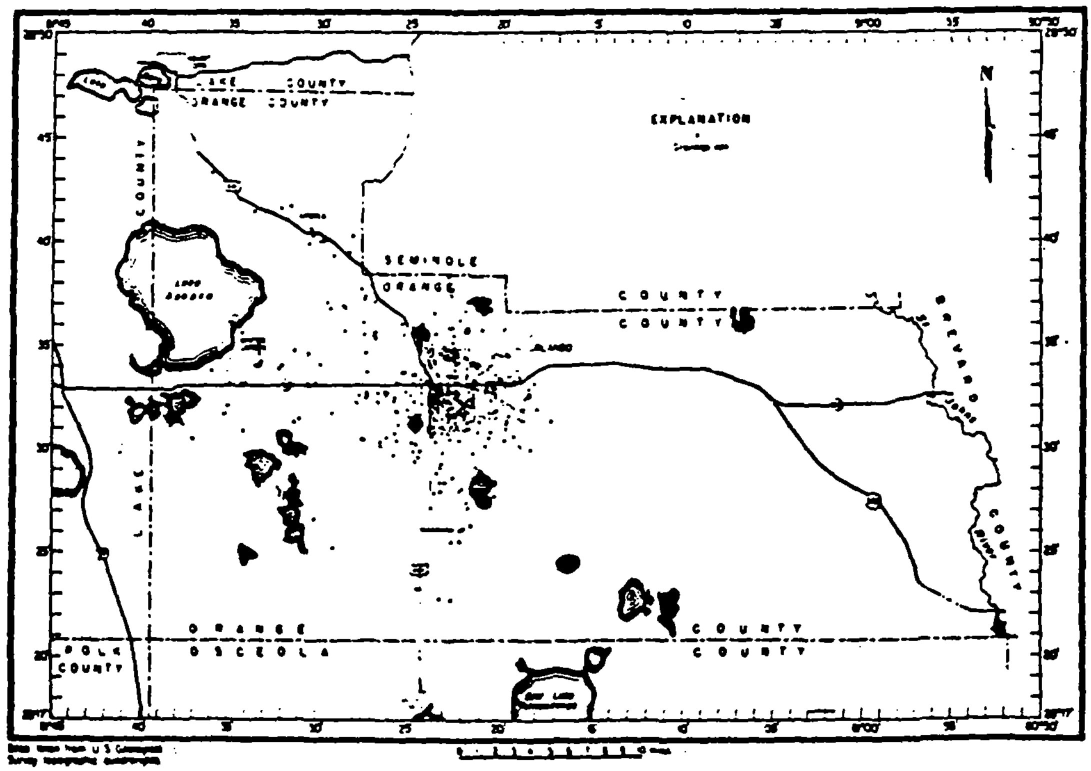

Figure 5. Location of drainage wells in Orange County, Fla., 1964.

TABLE 2. SUMMARY OF THE PROPERTIES OF THE GEOLOGIC FORMATIONS PENETRATED BY WATER WELLS IN ORANGE COUNTY, FLORIDA

Series	Formation name	Thickness, in feet	Description of material	Water-bearing properties	Aquifer	Water level
Recent and Pleistocene Pliocene(?)	Undifferentiated, may include Caloosahatchee Marl	0-200	Mostly quartz sand with varying amounts of clay and shell.	Varies widely in quantity and quality of water produced.	Non-artesian	0 to 20 feet below the land surface but generally less than 10 feet.
Miocene	Hawthorn	0-200	Gray-green, clayey, quartz sand and silt; phosphatic sand; and buff, impure, phosphatic limestone, mostly in lower part.	Generally impermeable except for limestone, shell, or gravel beds.	Shallow artesian, lower limestone beds may be part of Floridan aquifer.	Piezometric surface not defined, water level generally is lower than nonartesian aquifer and higher than Floridan aquifer.
	Ocala Group	0-125	Cream to tan, fine, soft to medium hard, granular, porous, sometimes dolomitic limestone.	Moderately high transmissibility, most wells also penetrate underlying formations.		

TABLE 2 CONTINUED

Eocene	Avon Park Limestone	400-600	Upper section mostly cream to tan, granular, porous limestone. Often contains abundant cone-shaped Foraminifera. Lower section mostly dense, hard, brown, crystalline dolomite.	Overall transmissibility very high, contains many interconnected solution cavities. Many large capacity wells draw water from this formation.	Floridan	Piezometric surface shown in figures 10 and 11.
	Lake City Limestone	Over 700 Total unknown	Dark brown crystalline layers of dolomite alternating with chalky fossiliferous layers of limestone.	Similar to Avon Park Limestone. Municipal supply of City of Orlando obtained from this formation.		

Geologic sections showing the formations and types of material are shown in figure 6.

FORMATIONS

The oldest formation penetrated by water wells in Orange County is the Lake City Limestone of middle Eocene age (about 50 million years old). The Lake City Limestone consists of alternating layers of hard, brown, porous to dense, crystalline dolomite and soft to hard, cream to tan, chalky, fossiliferous limestone and dolomitic limestone.

The Lake City Limestone is distinguished from the overlying Avon Park Limestone by the presence of the fossil *Dictyoconus americanus;* however, in Orange County, the rock in the depth interval (about 600-900 feet) where the top of the Lake City would normally be has been partly crystallized and the fossils have been badly damaged. Therefore, the exact location of the top of the formation is unknown. No water wells penetrate the total thickness of the Lake City, but the formation is probably more than 700 feet thick.

The Avon Park Limestone conformably overlies the Lake City Limestone and is composed of similar materials. The formation is distinguished from overlying formations by the occurrence of many sand-sized cone-shaped foraminifera. In many areas, the Avon Park is composed mostly of the shells of these tiny single-celled animals.

Contours on the top of the Avon Park Limestone are shown in figure 7. The thickness of the Avon Park is not accurately known because only a few wells penetrate the formation and the contact with the underlying Lake City Limestone is indistinct, but the Avon Park is probably 400 to 600 feet thick.

The Ocala Group[1] of the Florida Geological Survey overlies the Avon Park Limestone and contains the Crystal River, Williston, and Inglis Formations of late Eocene age. The limestone of the Ocala Group in Orange County was deeply eroded and in some areas entirely removed before the overlying formations were

[1]The term "Ocala Group" has not been adopted by the U. S. Geological Survey. The Florida Geological Survey uses Ocala as a group name as proposed by Puri (1953) and divided into three formations—Crystal River, Williston and Inglis Formations.

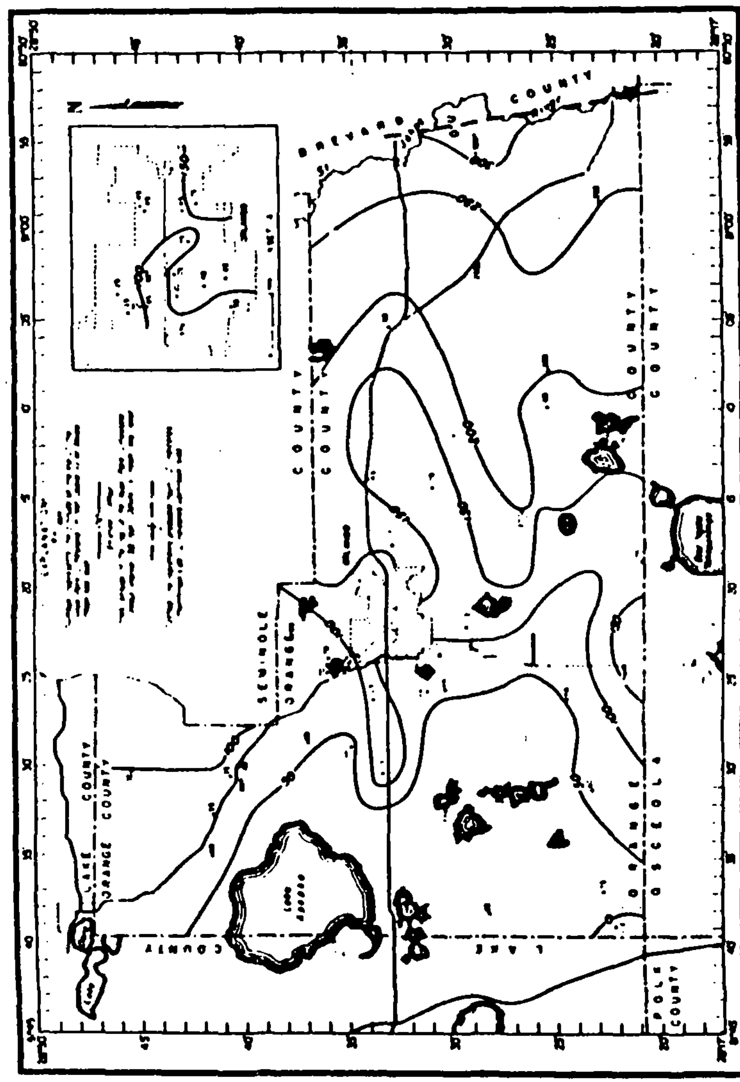

Figure 7. Configuration and altitude of top of the Avon Park Limestone, Orange County, Florida.

deposited. In south-central Orange County, formations of the Ocala Group are missing, but in the northeast part of the county near Bithlo the Ocala is about 125 feet thick. The contours on the top of the Eocene limestones in figure 8 show the eroded surface of the Ocala Group except where the Ocala is absent. In these areas the contours represent the top of the Avon Park.

The Hawthorn Formation of Miocene age (about 25 million years old) unconformably overlies the Ocala Group and, where the Ocala is missing, the Avon Park Limestone. The clayey sand of the Hawthorn Formation retards the vertical movement of water between the water-table aquifer and the underlying limestone of the Floridan aquifer. In most parts of the county the Hawthorn retards, to varying degrees, the downward seepage of the water from the water-table aquifer. In low lying parts of the county where the artesian head is above land surface the Hawthorn Formation retards the upward movement of water.

The lower part of the Hawthorn Formation usually contains more limestone than the upper part. The limestone sections usually contain much phosphorite and quartz sand and may grade into sandstone known locally as "salt and pepper rock." In the *northwestern part of the county*, the Hawthorn Formation has a higher percentage of limestone than in the southeastern part.

Orange County lies in the intermediate zone between the limestone-clay type of Hawthorn in north-central Florida and the clay-sand type of Hawthorn in south-central and southern Florida.

In Orange County the contact between the Hawthorn Formation and the underlying Eocene limestone is usually quite distinct; but the contact with the overlying deposits is gradational. The top of the Hawthorn is usually placed at the first occurrence of appreciable quantities of phosphorite or where a distinct and persistent greenish color appears. The Hawthorn is thickest (about 300 feet) in the southeastern part of Orange County and thinnest (about 50 feet) in the northwestern part of the county.

Undifferentiated sediments above the Hawthorn Formation may include the Caloosahatchee Marl (which has been designated Upper Miocene, Pliocene or Pleistocene by various workers)[7]; thick deposits of red clayey sand which occur near the surface in some areas in western Orange County; and marine terrace deposits. The red clayey sand is used extensively in road building.

[7]The U. S. Geological Survey gives its age as Pliocene.

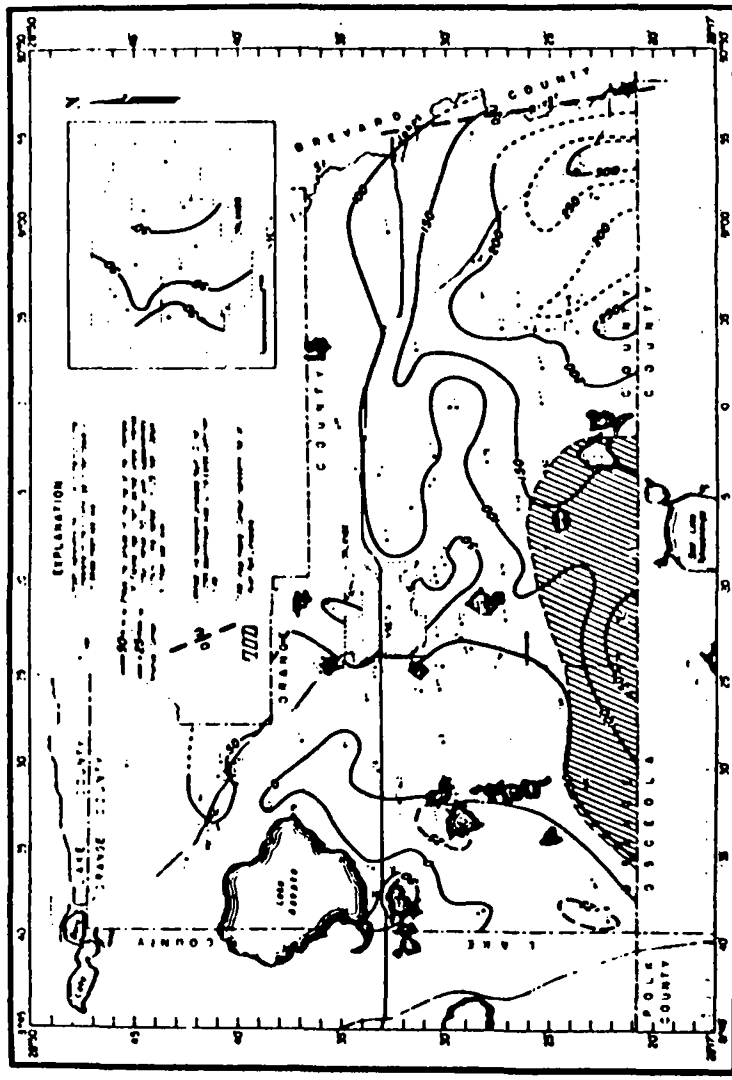

Figure 8. Configuration and altitude of top of the limestone of Eocene age, Orange County, Florida.

of type 2 flooding, the county often suffers soil moisture deficiencies at high-ground locations while lakes remain flooded in other areas.

The bed slopes of the streams that drain Orange County are so slight that velocities are not sufficient to cause appreciable erosion of the vegetation-filled channels. Consequently, the channels have not cut to depths that are below the water table when it is at even moderately low levels. Because of this most of the streams either cease flowing or recede to extremely low flow after only about 90 days of drought. To date, problems associated with low flow have been minimal in the country; but as the population and industrial complex expand, the need to dispose of wastes by way of streams may become more pressing. Because streamflow is small or nonexistent a large part of the time, streams cannot be used to transport wastes without becoming excessively polluted unless their base flows are improved or augmented. The base flow of a stream can be increased by deepening its channel to intercept the water table during droughts and cutting lateral ditches from the channel to increase the length of channel exposed to seepage. This would, of course, lower the water table adjacent to the channel and lateral ditches, but it would also improve the conveyance of the channel and the increased channel capacity would tend to reduce the height of flood crests. The flow of the streams could be augmented with water pumped from the artesian aquifer.

GROUND WATER

Ground water is the subsurface water in the zone of saturation—the zone in which all the openings of the soil or rock are completely filled with water. The source of all natural fresh ground water is precipitation which in Florida is almost entirely rain.

Ground water in Orange County occurs under nonartesian and artesian conditions. Nonartesian conditions occur when the upper surface of the zone of saturation (the water table) is not confined and, accordingly, is free to rise and fall directly in response to variation in rainfall and discharge. Artesian conditions occur where the water is confined and rises in wells above the point at which it is first penetrated.

NONARTESIAN AQUIFER

The nonartesian aquifer extends over most of the county and is composed mainly of quartz sand with varying amount of clay, hardpan and shell. In most parts of Orange County, the base of the aquifer is approximately 40 feet below the land surface. However, in parts of the highlands region, the nonartesian aquifer may extend to greater depths. Its permeability and thickness and, consequently, its productivity vary; and there are local areas where it does not yield much water. Most wells in the nonartesian aquifer are small diameter, sand-point or screened wells 20- to 30-feet deep that yield sufficient water for domestic use (5 to 10 gpm). In some areas open-end wells can be constructed by seating the casing in a hardpan or clay layer and then drilling through the hard layer and pumping out stand until a small cavity or "pocket" is formed below the hardpan or clay layer. The we'l is then pumped at a rate higher than the planned normal rate until it is virtually sand free so it will not yield sand when in normal use. Wells of this type usually yield more water (up to 30 gpm) and require less maintenance than sand-point or screen wells; but, in many areas of the county, geologic conditions are not favorable for their development.

WATER LEVELS

The water table in Orange County ranges from about 0 to 20 feet below the land surface except below some of the sand hills in the western part of the county where it may be considerably deeper. In the lowlands and flatwoods sections of the county, the water table is usually within a few feet of the land surface. The water table conforms in a general way to the configuration of the land surface, but it is usually at greater depths under hills and may be above the land surface in low swampy areas. The degree to which the water table conforms to the configuration of the land surface depends to a large extent on the permeability of the nonartesian aquifer and the materials below it. Other factors being equal, the water table follows the land surface closest where the permeability is least.

The water table fluctuates in response to changes in recharge and discharge in a manner similar to the fluctuation in the levels of lakes and reservoirs. Fluctuations of the water table range from a few feet in flat areas of the county to 15 feet or more in hilly areas. Figure 36 shows the water table fluctuation in a well on East Highway 50, about 1 mile east of Bithlo (well 832-105-3) and in a well on Hiawassee Road about a mile south of West Highway 50 (well 832-128-4). The hydrographs show that the Bithlo well fluctuated about 4.5 feet during the period of record while the

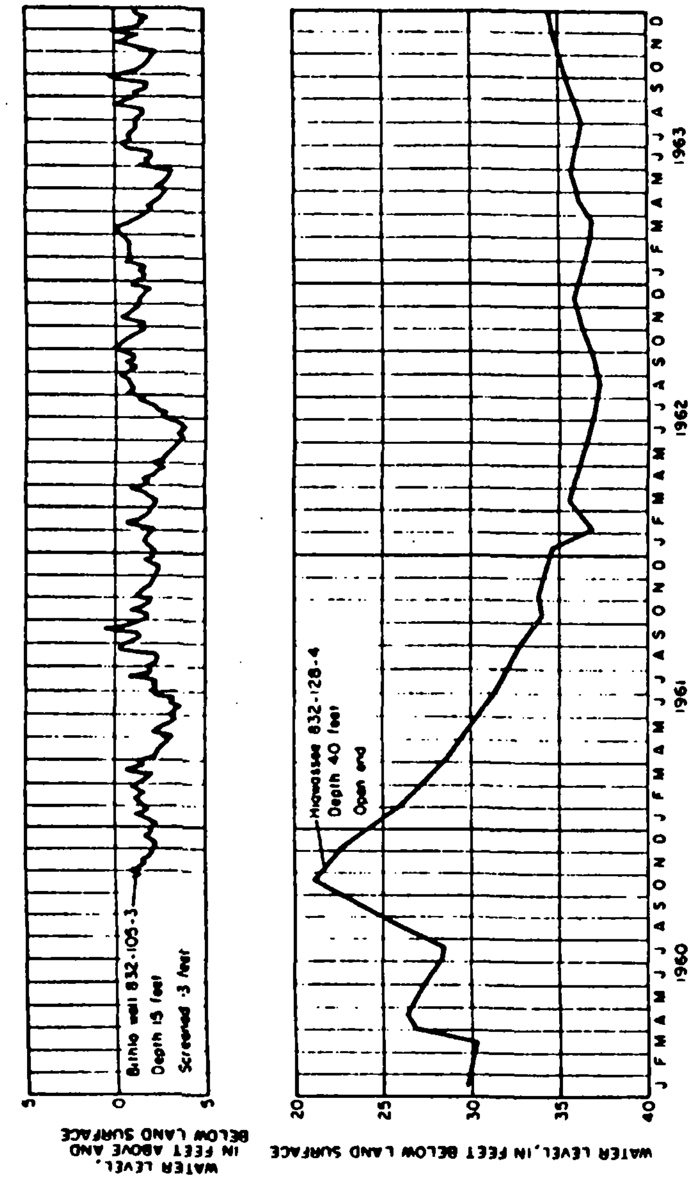

Figure 36. Hydrographs for wells near Bithlo and Hiawassee Road showing patterns of fluctuations of the water table.

Hiawassee well fluctuated about 16 feet. The hydrograph of the Hiawassee well is much smoother than the Bithlo well hydrograph, partly because the Hiawassee well is measured only once a month, whereas the Bithlo well has a continuous recorder and is plotted six times a month; but mostly because the water table is close to the land surface at the Bithlo well whereas it is 21 to 37 feet below the surface at the Hiawassee well. At Bithlo the water table reacts quickly to local showers and with prolonged rainfall quickly rises to the land surface where surface runoff occurs. During drought the water table quickly declines to a few feet below the land surface because surface drainage and evaporation can rapidly remove the water. However, once the water table is 3 or 4 feet below the surface, further decline is very slow because the streams have very shallow beds and cease to flow, evaporation practically ceases, and transpiration diminishes because most vegetation is shallow rooted. Also, lateral ground-water flow from the area is very slow because of the flat terrain; and downward leakage into the underlying artesian aquifer is slight because of the thick section of relatively impermeable marl and clayey sand that separates the nonartesian and the artesian aquifers.

At the Hiawassee well the water table is always 20 feet or more below the land surface. Rain filters slowly through the overlying sand, and the response of the water table to heavy rainfall or drought usually lags about a month. The water table fluctuations in this area reflect long periods of excessive and deficient rainfall. Brief showers after a dry period have little or no effect on the water table because the rain is held as soil moisture and returned to the atmosphere by evaporation and transpiration. However, the surface sands rapidly absorb even a heavy and prolonged rainfall and no surface streams flow from the area. The water that infiltrates below the root zone eventually seeps to the water table. After the water reaches the water table, it either seeps into nearby lowlying ponds (which occur to a considerable extent during periods of excessive rainfall) or it seeps downward into the artesian aquifer through the relatively thin and permeable clayey sand that separates the nonartesian and artesian aquifers. During droughts most of the ponds in the Hiawassee area go dry and the water table is mostly below the root zone, so it is apparent that further decline of the water table is due mostly to downward leakage into the artesian aquifer. The fluctuations of the water table in the Bithlo and Hiawassee wells reflect only natural changes as there is no appreciable pumping or irrigation in their vicinities.

RECHARGE

Most natural recharge to the nonartesian aquifer in Orange County comes from rain within or near the county. Some recharge comes from upward leakage of water from the artesian aquifer in areas where the piezometric surface is above the water table and from seepage from streams in areas where the streams are higher than the surrounding water table.

Artificial recharge to the nonartesian aquifer occurs by infiltration of water applied for irrigation, discharge from septic tanks, and by discharge from flowing wells.

Most of Orange County is blanketed with permeable sand which allows rain to infiltrate rapidly. In much of the eastern and southern parts of the county, where the land is flat and the water table is near the surface, the overlying surfaces and is quickly saturated during the rainy season; and the excess collects in swamps and sloughs or runs off in streams and rivers. In much of the western part of the county, the water table is far below the surface except in depressions. The surface sand can absorb rainfall at a rate of as much as 3.5 inches per hour with little or no direct surface runoff (Powell and Lewis, open-file report), and the large volume of sand above the water table holds large quantities of water which percolates slowly to the water table.

DISCHARGE

Discharge from the nonartesian aquifer in Orange County is by evapotranspiration, seepage into surface-water bodies, downward leakage to underlying aquifer, pumpage, and seepage into neighboring counties.

Ground water is removed from the zone of saturation and from the capillary fringe by the roots of plants and is given off to the atmosphere by transpiration. The depth to which plant roots penetrate depends on the type of plant and the soil, and ranges from a few inches to 50 feet or more for certain types of desert plants. In Orange County the maximum depth of tree roots is about 15 feet whereas the water table in most of the county is less than 15 feet below the surface; therefore, discharge of nonartesian ground water to the atmosphere by transpiration is appreciable.

Where the water table is near the land surface, ground water moves upward by capillary action through the small pores in the soil to the surface and evaporates. The rate of evaporation varies

with the depth to the water table, the porosity of the soil, the climate, the season and other factors.

The base flow of most streams in Orange County is maintained by seepage from the nonartesian aquifer. Seepage from the nonartesian aquifer also helps to maintain the levels of lakes and ponds during droughts.

Practically all natural recharge to the Floridan aquifer in Orange County passes through the nonartesian aquifer. In the western part of the county, downward leakage is probably the principal form of discharge from the nonartesian aquifer. Seepage of nonartesian water out of the county is probably small.

Water is pumped from the nonartesian aquifer for lawn irrigation, stock watering, and domestic use. Most wells are small 1¼- to 2-inch sand-point wells which yield about 5 to 10 gpm.

QUALITY OF WATER

Several factors influence the quality of the nonartesian ground water in Orange County. Rain recharging the aquifer dissolves soluble material contacted such as fertilizer and insecticides. Drainage from septic tanks percolates to the nonartesian aquifer. Harmful bacteria and color are usually removed if the recharge water percolates through sand. Some of the very shallow wells located in swampy areas yield water with high color. Most of the nonartesian ground water that is soft and low in mineral content has low pH indicating that it is corrosive. In areas where the piezometric surface is above the water table, upward leakage occurs and the nonartesian water is more highly mineralized.

The dissolved mineral content of water from wells in the nonartesian aquifer varies greatly depending on the composition of the aquifer. The water from wells developed in clean quartz sand is usually very soft (hardness generally less than 25 ppm) and low in mineral content (about 25 to 50 ppm). The following is a typical analysis of water from a well in western Orange County (838-128-1) developed in clean quartz sand:

Silica (SiO_2)	2.5	ppm	Dissolved solids	21	ppm
Iron (Fe)	.45	ppm	Specific conductance	39	micromhos at 25°C
Calcium (Ca)	.8	ppm			
Magnesium (Mg)	.7	ppm	Bicarbonate (HCO_3)	5	ppm
Sodium (Na)			Sulfate (SO_4)	2.8	ppm
Potassium (K)	.0	ppm	Chloride (Cl)	5.5	ppm
Fluoride (F)	0.1	ppm	pH	5.2	units

Nitrate (NO_3)	.0	ppm	Color	8 units
Hardness as $CaCO_3$	5	ppm		

The relatively high iron content (.45 ppm) was probably due to iron dissolved from the casing or pump by the water of low pH (5.2). The water from a well (832-101-2) at Christmas in eastern Orange County had an iron content of 4.5 ppm. This high iron content probably came from the aquifer because the neutral pH of the water, 7.0, indicates that it is not corrosive.

Total mineral content as high as about 500 ppm and high concentration of some constituents indicate that the water in some wells in the nonartesian aquifer is polluted. The water from a well (822-138-3) in the southwestern part of Orange County had a dissolved mineral content of 530 ppm (estimated from a conductivity measurement). Concentrations of other constituents were potassium, 10 ppm, sulfate, 107 ppm, and nitrate, 173 ppm, which definitely indicates a nearby source of pollution. Use of water containing an excess of about 45 ppm of nitrate for feeding formulas for infants results in metheglobinemia or cyanosis (blue babies) in the infants. The water from some of the shallow wells had as much as 90 units of color.

SECONDARY ARTESIAN AQUIFERS

Several secondary artesian aquifers occur locally within the confining beds of the Hawthorn Formation and less extensively within the formations above the Hawthorn. These aquifers are usually found at depths ranging from about 60 to more than 150 feet below the land surface and are composed of discontinuous shell beds, thin limestone lenses or permeable sand-and-gravel zones. The secondary artesian aquifers are most productive in tthe area east and south of Orlando where they generally yield sufficient water for domestic use. Open-end cased wells can sometimes be constructed in the secondary artesian aquifers, but screens are often necessary to keep sand from the well and to obtain sufficient water.

WATER LEVELS

A continuous record of the water levels of a secondary artesian aquifer have been recorded in a well about 1 mile east of Bithlo

(832-105-2), figure 37. The casing of this well extends 75 feet below land surface into a 12-foot shell bed. At this site there is also a record of the fluctuations of the water table (well 832-105-3) and the fluctuations of the piezometric surface of the Floridan aquifer (well 832-105-1). The water level of the secondary artesian aquifer is always below the water table and above the piezomtric surface of the Floridan aquifer at this site. This relation probably exists wherever the water table is continuously above the piezometric surface. At this location the secondary artesian water level is 6 to 12 feet below the water table and 6 to 14 feet above the water level in the Floridan aquifer. The range of fluctuation of the water level in the secondary artesian aquifer for the period of record was about 3½ feet or from 7 to 10½ feet below land surface. The secondary aquifer water level does not respond rapidly to rainfall. The recorder chart usually shows very little daily fluctuation, however there is a gradual long-term decline or

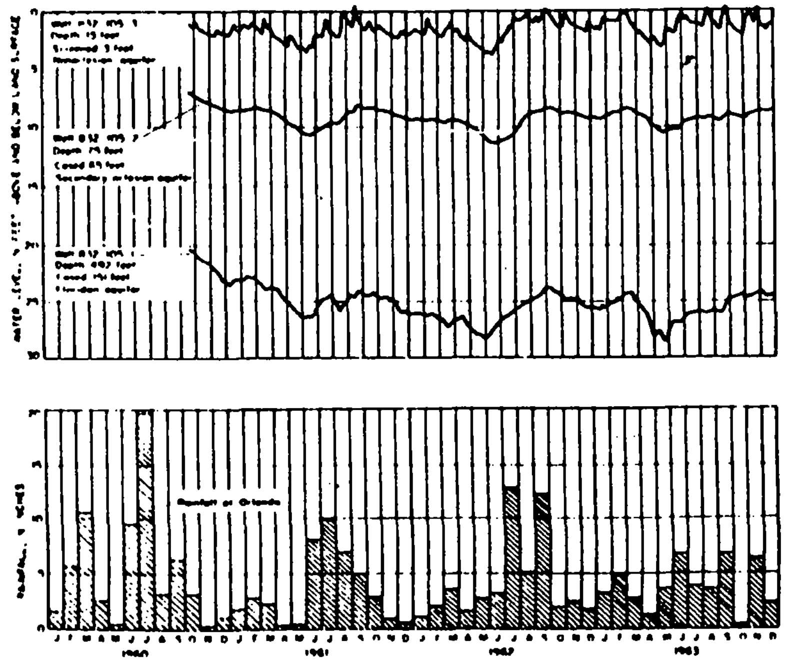

Figure 37. Relationship between water levels at Bithlo and rainfall at Orlando.

rise that corresponds to general wet or dry periods. This indicates that water enters and leaves the aquifer at a slow rate, and the hydraulic connections to the overlying and underlying aquifers are probably rather poor.

RECHARGE

Recharge to the secondary artesian aquifers in Orange County is by downward leakage from the nonartesian aquifer in most parts of the county and by upward leakage from the Foridan aquifer where the piezometric surface of the Floridan aquifer is above the piezometric surface of the secondary artesian aquifers. A small amount of water probably flows into the county from secondary artesian aquifers in surrounding counties. The secondary artesian aquifers are the least likely to be polluted because the overlying, low-permeability beds tend to protect them from surface pollution, and drainage wells are usually cased through the secondary artesian aquifer zone.

DISCHARGE

Water discharges from the secondary artesian aquifers by downward leakage to the Floridan aquifer, upward leakage to the nonartesian aquifer where the piezometric surface is above the water table, underground flow out of the county, and pumpage.

QUALITY OF WATER

The quality of water in the secondary artesian aquifers in Orange County varies with location, depth, and the local hydrology. In areas where the piezometric surface of the secondary artesian aquifer is below the water table, downward leakage from the water table aquifer occurs and the water tends to be similar to the nonartesian water except where additional solution has taken place within the aquifer. In areas where the piezometric surface of the Floridan aquifer is higher than the piezometric surface of the secondary artesian aquifer, upward leakage occurs from the Floridan aquifer and the water in the secondary aquifer tends to be similar to the water in the Floridan aquifer.

Generally, the dissolved-solids content of the water in the secondary artesian aquifers ranges from 100 to 400 ppm. The predominating ions usually are calcium and bicarbonate. Water from secondary artesian aquifers is sometimes more mineralized than is water from the Floridan aquifer. For example: The water from a 75-foot deep well at Bithlo (832-105-2) constructed in a secondary artesian aquifer had a dissolved solids content of 380 ppm. The water from an adjacent 492-foot deep well in the Floridan aquifer had a dissolved solids content of 290 ppm.

FLORIDAN AQUIFER

The principal artesian aquifer in Orange County is part of the Floridan aquifer that underlies all of Florida and parts of Alabama, Georgia, and South Carolina. The Floridan aquifer, as defined by Parker (1955, p. 189) includes "parts or all of the middle Eocene (*Avon Park and Lake City limestones*), *upper Eocene* (Ocala limestone), Oligocene (Suwannee limestone), and Miocene (Tampa limestone) and permeable parts of the Hawthorn formation that are in hydrologic contact with the rest of the aquifer."

AQUIFER PROPERTIES

The Floridan aquifer is one of the most productive aquifers in the country. In Orange County many large diameter wells (20 inches or more) yield more than 4,000 gpm. These wells can be constructed in almost any area of the county. Wells that will yield only small quantities of water are usually in the vicinity of sinkholes where sand has filled solution channels in the aquifer. Pumping rate—drawdown ratios range from less than 100 gpm per foot of drawdown to over 500 gpm per foot of drawdown. The aquifer consists of nearly 2,000 feet of porous limestone and dolomite or dolomitic limestone covered by sand and clayey sand ranging in thickness from a few feet to about 350 feet. The altitude and configuration of the top of the Floridan aquifer is shown in figure 38. The depth below land surface to the top of the aquifer is shown in figure 39. The total thickness of the aquifer is not accurately known because the deepest water well in the county penetrates only the upper 1,400 feet. The log of an oil test hole drilled southeast of Orlando shows dense anhydrite at about 2,000 feet, and this is assumed to be the base of the aquifer.

The lithologic and hydrologic character of the Floridan aquifer is not uniform either horizontally or vertically. In general, there are alternating layers of limestone and dolomite or dolomitic limestone. The limestone layers are usually softer and of lighter color than the dolomitic layers. The aquifer stores huge quantities of water and also acts as a conduit. Water moves slowly through

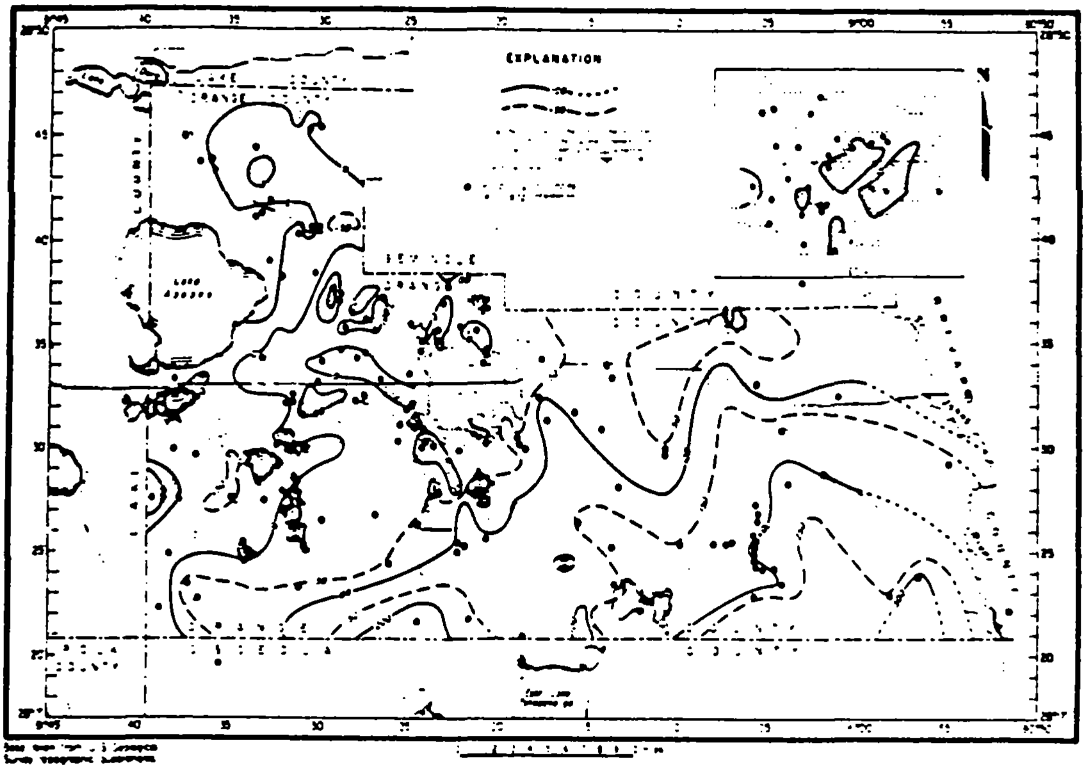

Figure 38. Configuration and altitude of the top of the Floridan aquifer in Orange County, Florida.

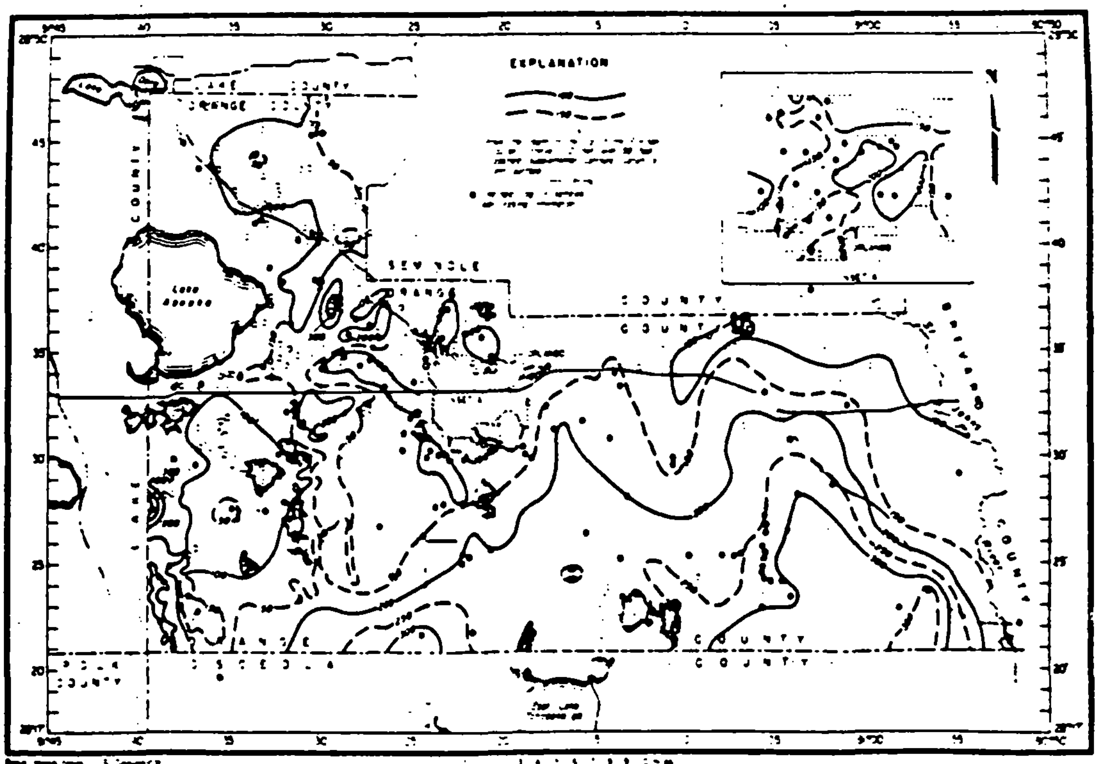

Figure 39. Depth below land surface to the top of the Floridan aquifer in Orange County, Fla.

the rock from areas of recharge to areas of discharge. The entire aquifer has been affected to some degree by the dissolving action of ground water and is somewhat analogous to an enormous sponge.

Some of the largest known caverns in Florida have been found within the Floridan aquifer in Orange County. One of the largest caverns with no opening to the surface ever discovered in Florida was encountered in a city supply well drilled in the southwest part of Orlando. This cavern was 90-feet high with the ceiling 573 feet below the land surface. The cavern was filled with water and there was 12 feet of black organic muck on its floor. The areal extent of this cavern is unknown, but several deep wells 1,000 feet to the north did not penetrate it. One of the deepest and largest known caverns in Florida is a sinkhole near Little Lake Fairview, northwest of Orlando, known as Emerald Springs. Emerald Springs was measured in 1956 and found to extend 334 feet below the water surface which is about 45 feet below the surrounding land surface. According to divers who have explored the sinkhole, it has sloping sand-covered sides for 45 feet below the water surface and then a vertical neck, about 20 feet in diameter, through limestone for about 45 feet. Below this depth, there is a large room with a sloping ceiling. The wall of the room was found at a distance of 89 feet in one direction but had not been found at a distance of 100 feet in the opposite direction (when the divers were forced to return to the surface).

Zones of the Aquifer

The Floridan aquifer in central Orange County has two major producing zones that are separated by a relatively impermeable zone. The upper producing zone extends from about 150 feet below the land surface to about 600 feet. The lower producing zone extends from about 1,100 feet to 1,500 feet or more below the land surface. Both major producing zones are composed of hard brown dolomitic limestone or dolomite and relatively soft cream limestone; however, the top half of the upper zone is mostly soft limestone. Some of the dolomite in both major producing zones is very dense, but many interconnecting solution cavities make the overall permeability of both zones very high.

The limestone in the top half of the upper zone is mostly white, soft, granular, and fossiliferous. This limestone contains cavities, but they are usually neither as large nor as numerous as the cavities in the dolomitic parts of either major producing zone. At some locations, very large (4,000 gpm or more) yields can be obtained from the limestone, but most high yield wells also penetrate the underlying dolomitic limestone. However, many domestic wells and small public supply wells draw all their water from the limestone section of the upper zone. The municipal supply wells for the Cities of Orlando and Winter Park are developed in the lower (1,100-1,500 feet) producing zone. These wells generally yield 3,000 to 5,000 gpm with 10 to 25 feet of drawdown.

The relatively impermeable zone (600 to 1,100 feet below the land surface) separating the two major producing zones is composed of layers of relatively soft, mealy limestone and dolomitic limestone. It contains some water-bearing layers, but generally this separating zone yields much less water than the zones above and below it. In many parts of the country the separating zone would be considered a good aquifer; but because much larger supplies can be obtained above and below this zone in Orange County, very few wells are developed in it.

The occurrence of reported cavities is shown in figure 40. The number of cavities shown for different depths actually does not represent the true distribution of the cavities because many more wells penetrate the upper part of the aquifer than penetrate the lower part. However, the illustration does show that although cavities have widespread vertical distribution, they are more prevalent in some zones than in others.

Interrelation of Zones

The interrelation of the upper and lower producing zones is of vital importance to the people of Orlando and Winter Park because excess surface water is disposed of in the upper zone while most of the municipal water supplies are developed from the lower zone. Contaminated water can enter the upper producing zone through the numerous drainage wells. (See section on drainage wells, page 33) and it is important to know if this contaminated water can move into municipal supply wells.

It has been postulated that some dense dolomitic beds between 400 and 600 feet in the upper zone might be continuous and act as an impervious layer to protect the lower zone. To test this idea, a well was drilled at Lake Adair in Orlando into the upper zone of the aquifer adjacent to an existing well in the lower zone. The shallow well is cased to the top of the aquifer (105 feet) and bottomed at the top of the hard dolomitic zone at 400 feet. The

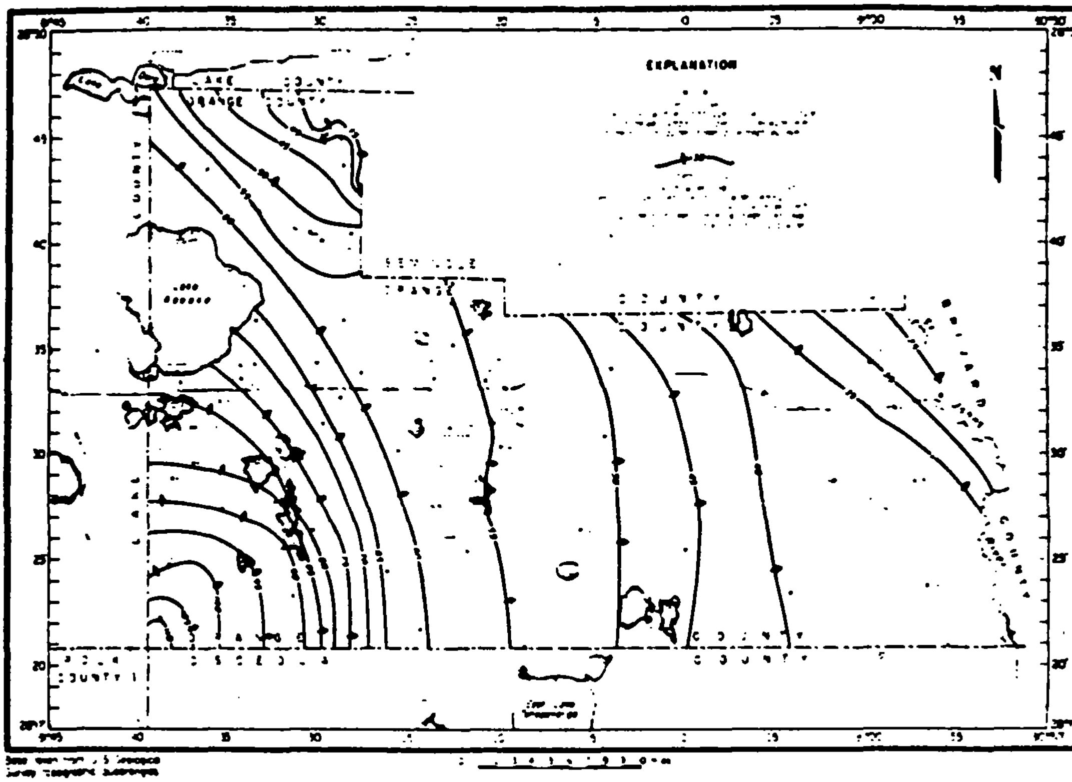

Figure 48. Contours of the piezometric surface at about normal conditions, December 11-17, 1963.

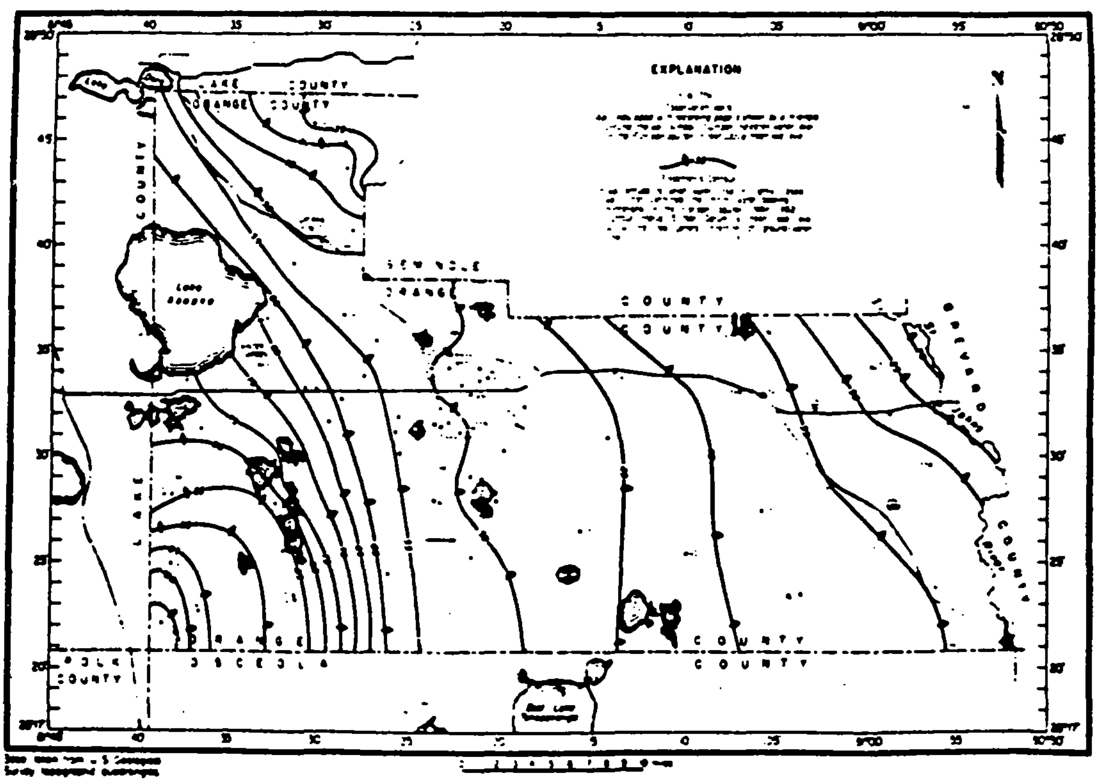

Figure 49. Contours of the piezometric surface at extreme low-water conditions, May 1962.

Water moves downgradient from areas of high piezometric level to areas of low piezometric level. In general, the direction of movement, shown by the arrows in the figures, is at right angles to the contour lines, although locally the direction of flow may be different because of differences in permeability such as caused by cavern systems.

Figure 46 depicts the piezometric levels in September 1960, the highest observed during the investigation. The high levels of September 1960 equalled or exceeded the highest previous recorded levels which occurred in the early 1930's. Figures 47 and 48 which show the piezometric surface in July 1961 and December 1963 represent about normal conditions; figure 49 shows the piezometric surface in May 1962 when artesian levels were at their lowest for the period of record 1943 through 1963. The relation of the piezometric surface to the land surface is shown in figures 50 and 51. Figure 50 shows the distance above and below land surface of the static water level in tightly cased wells in the Floridan aquifer during extremely high-water conditions (Sept. 1960). Figure 51 shows the distance above and below land surface of the static water level in tightly cased wells in the Floridan aquifer during extremely low-water conditions (May 1962).

Fluctuations

Gages were installed on six wells in the Floridan aquifer to record the fluctuations of the piezometric surface (figures 37, 41, 52, and 53). In addition, water levels were measured periodically in about 70 wells. Most water-level fluctuations are caused by changes in rates of recharge (mostly rainfall) and/or discharge. However, variation in barometric pressure, temporary loading of the land surface such as by-passing of trains and earthquakes also cause fluctuations. For example, the Alaskan earthquake of March 27, 1964 created a brief surge of more than 10 feet in the water levels of some wells in Orange County.

The sharp rises in the water levels in well 833-120-3 at the Orlando Air Force Base (figure 52) and well 932-128-1 west of Orlando (figure 53) are caused by rapid recharge through the many drainage wells in the area. The nearly equally sharp declines following the rises show that the water mound created by the drainage wells rapidly dissipated through the porous limestone. Although the water probably moves slowly, the pressure is transmitted relatively rapidly to other parts of the aquifer

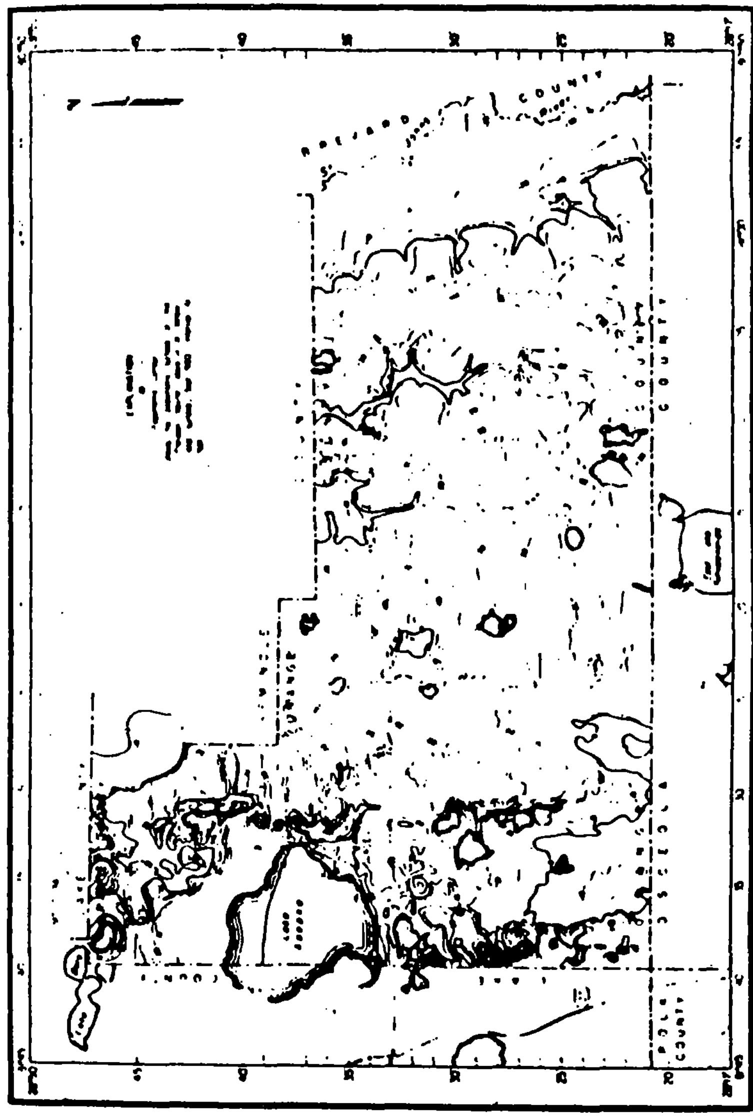

Figure 50. Piezometric surface relative to land surface datum, at high-water conditions, September 1960, Orange County, Florida.

caused only a relatively small decline in water levels. Most of the fluctuations shown by the hydrograph on figure 53 are caused by variations in recharge; however, as pumpage increases in the future, continuing decline of average water levels near the centers of heavy pumping can be expected.

Before man began to withdraw and inject water, the artesian aquifer was in hydrologic equilibrium; that is, over climatic cycles the amount of discharge from the aquifer equalled the recharge. The average slope of the piezometric surface adjusted to the average discharge and the average recharge. Withdrawal of water by wells is a new discharge from the system which must be balanced by a reduction in natural discharge, an increased recharge or a combination of the two if a new equilibrium is to be reached. To reduce natural discharge, the slope of the piezometric surface between the area of pumping and the area of natural discharge must be reduced so that less water flows to the discharge points. When piezometric levels are lowered in recharge areas, the head difference between the water table and the artesian aquifer is increased which tends to cause an increased rate of recharge, thereby salvaging water that would normally flow off in streams or be lost to evapotranspiration. Thus, it is obvious that some lowering of the average piezometric levels is necessary if water is used.

If pumping rates are stabilized, the piezometric surface eventually will stabilize at a new equilibrium slope—providing the average pumpage does not exceed the reduction in natural discharge and the increase in recharge. A continued increase in pumping will will result in a continued lowering of average piezometris level.

RECHARGE AREAS

Most of the recharge to the Floridan aquifer in Orange County is from infiltration of rain through the relatively thin, semipermeable confining beds in the highlands section and through the more than 300 drainage wells in the county. A lesser quantity enters the county by underground flow from southern Lake County and a small amount enters from Osceola County. A knowledge of the areas where rainfall can recharge the Floridan aquifer is necessary if development of Orange County is to be planned to protect the future water supplies of the area. Several methods can be used to delineate these areas. One method is by analysis of hydrologic and geologic data. Figure 54 shows the limits of the

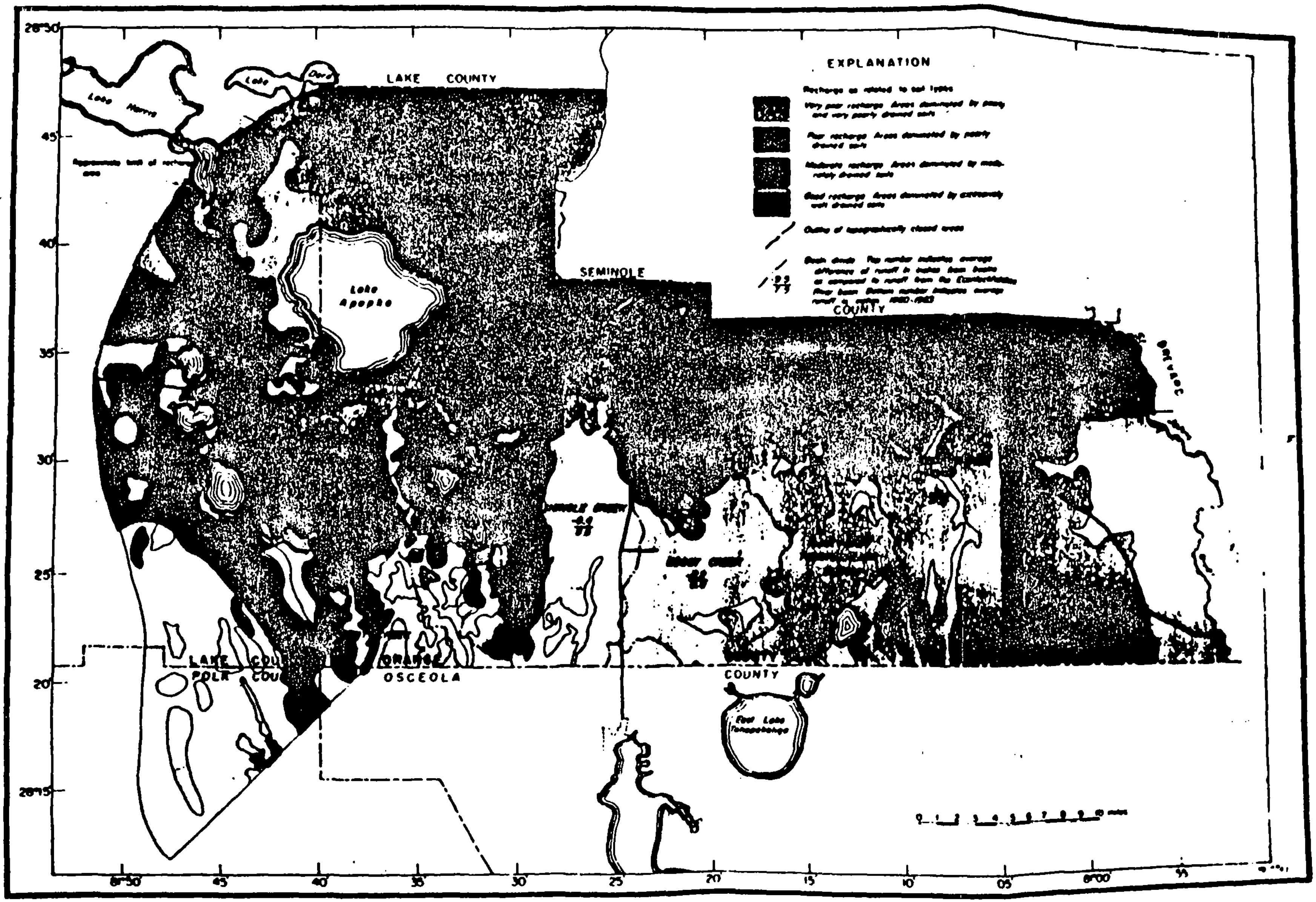

Figure 54. Recharge areas to the Floridan aquifer in Orange County and selected adjacent areas, Florida.

area—based on the configuration of the piezometric surface shown in figure 45—that might contribute recharge to the Floridan aquifer in Orange County.

Water level records of lakes, the nonartesian aquifer, and the Floridan aquifer show that lake levels and the water table are above the piezometric surface in most of Orange County (figs. 50 and 51) and rain will infiltrate and recharge the Floridan aquifer in most parts of the county if the confining bed overlying the aquifer is not impermeable. A study of the geologic logs of wells shows that the confining bed generally is much thinner and more permeable in the rolling highlands in the western part of the area than it is in the rest of the county (figs. 3, 6, and 39); therefore, rain can infiltrate to the Floridan aquifer much more easily in the highlands than in the lowlands.

Analysis of the hydrographs of wells in the Floridan aquifer (figs. 37, 41, 52, and 53) and rainfall records show that the water levels in wells in the highlands respond to rainfall much more rapidly and with much greater magnitude than do wells in the rest of the county. This indicates that much more recharge is entering the Floridan aquifer in the highlands than elsewhere.

Another method of delineating recharge areas is by analysis of the mineral content of water from the aquifer. In general, water in recharge areas is less mineralized than in other areas. Therefore, if allowance is made for the varying solubilities of the materials in and above the aquifer and if there is no outside contamination, the less the mineralization of the water the closer it is to recharge areas. Figure 55 shows the dissolved solids in water in the aquifer in Orange County. The values when analyzed in conjunction with the piezometric maps indicate that there is an effective recharge area in and near western Orange County.

A third method of evaluating recharge areas is by computing the quantity of water which enters and leaves an area by underground flow. The difference between the two is the net recharge within the area. The net recharge plus any discharge (pumpage, spring flow or natural seepage) is the recharge within the area. The net recharge (outflow minus inflow) within Orange County was calculated to be an average rate of about 35 mgd in 1961. Pumpage was about 65 mgd, spring flow and seepage were estimated to be 110 mgd; therefore, total recharge was about 210 mgd. The weakness of this method is that the transmissibility (T) of the aquifer may not be uniform and the T values used in the computation may not be representative of the aquifer.

Analytical results in micrograms per liter

Aluminum	13	Germanium	< .29
Beryllium	< .57	Iron	< .29
Bismuth	< .29	Manganese	< 1.4
Cadmium	< 1.4	Molybdenum	.54
Chromium	< 1.4	Nickel	.63
Cobalt	< 1.4	Lead	< 1.4
Copper	< 1.4	Titanium	< .57
Gallium	< 5.7	Vanadium	< .29
		Zinc	< 5.7

These concentrations are well within the recommended limits set by the U. S. Public Health Service. The symbol < indicates that the concentrations are less than the values shown which are the lower detection limits.

The temperature of the water in the Floridan aquifer in Orange County ranges from 71 ° to 77°F (See fig. 59.). In general, the temperatures of the water increase with increased depth in the aquifer. This is probably due to the natural geothermal gradient of the earth.

SALT-WATER CONTAMINATION

The only known occurrence of salt-water contamination of ground water in Orange County is in the eastern part of the county (fig. 58). The high salt content of the water in this area is probably due to incomplete flushing of sea water that entered the aquifer when the ocean last covered this part of Florida, rather than to direct encroachment from the present-day ocean. In coastal areas where fresh water and sea water are in hydrostatic balance with each other, the Ghyben-Herzberg ratio can be used to calculate the approximate depth at which sea water will be found. The Ghyben-Herzberg ratio is based on the relative weight of fresh water and sea water (1:1.025) and indicates that 41 feet of fresh water are required to balance 40 feet of sea water. This means that for every foot of fresh water head above msl, there should be at least 40 feet of fresh water below msl. Applying this ratio in the Cocoa well field area in eastern Orange County (fig. 5) where the average piezometric head is about 40 feet above msl (fig. 47), there should be fresh water in the aquifer to a depth of at least 1,600 feet below msl; yet a pilot well drilled in the area

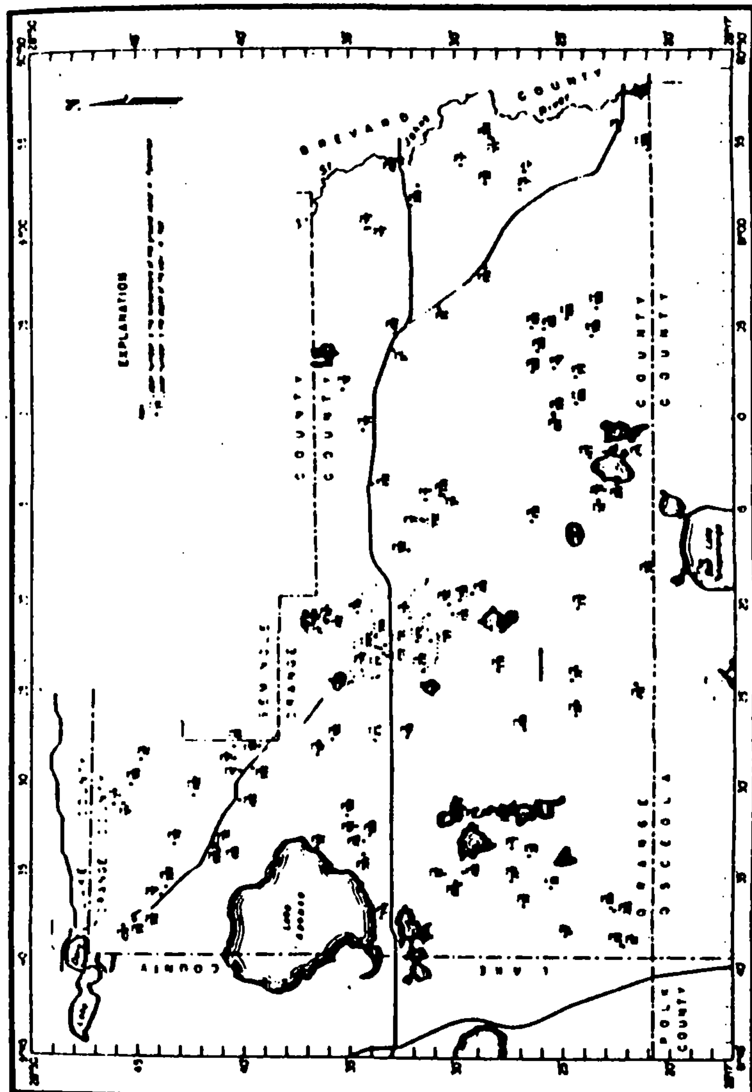

Figure 59. Temperature of ground water in Orange County, Florida.

DRAINAGE WELLS

HISTORY

The first drainage well in Orange County was drilled about 1904. Since that time about 400 drainage wells have been drilled in the county. The data on 392 drainage wells will be listed in an Information Circular in preparation (1967) that will be titled "Water Resources Records of Orange County, Florida." Quite a few drainage wells probably are not included because prior to 1939 it was not necessary to obtain a permit to install such wells; and even after 1939, a number of wells probably were installed without permits. No public record has been kept of many drainage wells. The most active year for drilling of drainage wells was 1960 when about 35 wells were constructed.

POLLUTION

The possibilities of pollution of ground-water supplies by drainage wells was described in detail by Unklesbay (1944) and by Telfair (1948). Unklesbay states (Ibid p. 25), "water which drains from roadside ditches or street gutters, and especially that discharged from septic tanks, is almost certain to be polluted, and the freedom of circulation allowed by cavernous limestone may permit such waters to enter supply wells without being subject to filtration." Telfair (p. 8-9) shows that in a test at Live Oak, where the limestone aquifer is similar to that in Orange County, salt put in a well was detected in an observation well 600 feet away 15 minutes later. Thus, water can move through the aquifer at speeds of at least 40 feet per minute if hydrologic conditions are favorable.

Under natural conditions, ground water moves very slowly—usually less than a few feet a day. However, when the natural conditions are altered, as occurs when drainage from a well builds up a local mound and pumping from a nearby supply well creates a cone of depression, the gradient between the two wells is greatly steepened so that in cavernous limestone, water moves rapidly from a drainage well to a supply well.

The quality of the water flowing down drainage wells in Orange County varies from practically pure rain water to highly polluted water. An example of polluted water entering the aquifer is a drainage well (826-125-1) that receives water used to flush cow barns at a dairy as well as surface drainage. The water entering

this 142-feet deep well carries appreciable quantities of cow manure. On January 8, 1964, the water draining into the well had the following concentrations in ppm: sodium, 58; potassium, 54; chlorides, 64; fluorides, 3.8; and phosphates, 34. All of these concentrations are much higher than the natural water of the area. Water from a 289-foot deep well (836-125-2) which is 1,000 feet downgradient from well 836-125-1 had the following mineral concentrations in ppm on March 16, 1964: sodium, 15; chlorides, 13; and fluorides, 0.6. These concentrations are abnormally high for the area and indicate that polluted water from the drainage well is probablly entering the supply well. Another drainage well near Winter Garden (833-134-2) receives water from tile drains that underlie a citrus grove. On January 8, 1964 the water entering this well had the following concentrations of mineral constituents in ppm: sodium, 15; potassium, 15; sulfate, 156; chloride, 48; fluoride, 2.0; and nitrates 104. All of these concentrations are much higher than the concentrations in the natural water in the area. The higher than normal concentrations of potassium and nitrates definitely indicate pollution from fertilizer.

General areas where bacterially polluted water has been found in some wells by the Orange County Health Department are shown in figure 60. Most wells in the indicated areas are probably not polluted but the map shows areas where pollution is more prevalent than in other areas of the county. Orange County Health Department records show that in the 5-year period 1959-1964 approximately 50 wells showed evidence of bacterial pollution. The indicator bacteria are not harmful but indicate that harmful organisms could be present. It is probable that many private wells have at some time contained polluted water, but it was not discovered because samples were not taken for bacterial analyses.

A salt test similar to the Live Oak test was made in Orange County in March 1961 by the Orange County Health Department. A drainage well located in the northwestern corner of Lake Pleasant in the northwestern part of Orange County was suspected of causing pollution in nearby supply wells. Within a few hours after water from the lake was allowed to drain into the well on September 24, 1960, water from supply wells in the area became polluted. Water pumped from the Northcrest Public Supply well which is located 1,000 feet to the northwest and cased 60 feet deeper than the bottom of the drainage well suddenly became muddy, high in bacteria count, and had an unpleasant taste and odor. The pollution cleared up after the drainage well was shut down and returned

STATE OF FLORIDA
DEPARTMENT OF NATURAL RESOURCES
Elton J. Gissendanner, *Executive Director*

DIVISION OF RESOURCE MANAGEMENT
Art Wilde, *Director*

BUREAU OF GEOLOGY
Walter Schmidt, *Chief*

SPECIAL PUBLICATION NO. 29

KARST IN FLORIDA

by

Ed Lane

Published for the
FLORIDA GEOLOGICAL SURVEY
TALLAHASSEE
1986

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LETTER OF TRANSMITTAL

Bureau of Geology
Tallahassee, Florida

August, 1986

Governor Bob Graham, Chairman
Florida Department of Natural Resources
Tallahassee, Florida 32304

Dear Governor Graham:

The Bureau of Geology, Division of Resource Management, Department of Natural Resources, is publishing as its Special Publication No. 29, *Karst In Florida*. This report explains the origins of Florida karst, gives examples of its occurrence throughout the State, and discusses benefits, hazards, and what can be done about it. This publication will be useful to professionals in earth-science related fields, teachers, governmental agencies, and the citizens of Florida.

Respectfully yours,

Walter Schmidt, Chief
Bureau of Geology

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1986

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TABLE OF CONTENTS

Page

ILLUSTRATIONS

TABLES

KARST IN FLORIDA

by
Ed Lane

INTRODUCTION

Familiar features of surface drainage systems are streams, rivers, and lakes (all interconnected) which cross the land and eventually discharge into an ocean. In contrast, karst terrains have drainage systems that are distinctly different from these surface drainage systems. Karst terrains develop in areas underlain by carbonate rocks, primarily limestone and dolomite, and have drainage which is manifested by sinkholes, springs, caves, disappearing streams and underground drainage channels. Karst topography is usually irregular due to the solution activity of acidic surface and groundwaters, which dissolve the carbonate rocks, forming cavities and allowing surficial sediments to collapse or subside.

Carbonates are a large group of minerals which have as a common constituent the carbonate ion (CO_3). When combined with other elements these carbonate ions form various carbonate minerals, of which the three most common are calcite and aragonite ($CaCO_3$), and dolomite ($CaMg(CO_3)_2$). Calcite is by far the most abundant carbonate mineral. It occurs as enormous and widespread sedimentary deposits in which it is the predominant mineral. In pure limestones, some of which occur in Florida, calcite makes up 98 to 100 percent of the rock. Practically all carbonate rocks in Florida are limestone or dolomite, with limestone predominant.

It has been estimated that limestones and dolomites constitute about 20 percent of all sedimentary rocks (Gilluly, et al., 1959), and that 5 to 10 percent of earth's land surface is karstic (Jackson, 1982). Because carbonate rocks comprise such a large proportion of the rocks on or near the earth's surface, karst terrains occur in many parts of the world.

The classic karst area, from which the name is derived, is the Karst district of Yugoslavia, near the eastern shore of the Adriatic Sea. It is nearly 100-miles wide in places, with the entire district approximating the area of New York State. There, the limestone rocks are honeycombed by tunnels and caverns, so that most of the drainage is underground. Large sinkholes are abundant, some as deep as 600 feet. Streamless valleys are common since streams often disappear into swallow holes (American Geological Institute, 1962, p. 271). Streams tend to have intermittent surface flow for short times after rain or snow melt. The hummocky terrain is characterized by deeply eroded, isolated valleys and steep-sided hills. These geomorphic features are so characteristic of the Yugoslavian Karst district that the generic term *karst terrain* has been universally applied to them, meaning terrain that has been shaped by dissolution of the underlying carbonate rocks.

Karst regions in the United States include the caves and sinks region of southern Indiana; central Kentucky and Tennessee, which has the Mammoth Cave system; the Carlsbad Cavern region of southern New Mexico; the Appalachian Mountain's Great Valley limestone belt, which has Natural Bridge and Luray Caverns; and Florida's extensive karst plains, sinkhole lakes and caves.

Why study karst? Figures 1, 2, and 3 show the significance of karst in Florida and why concern is justified. An understanding of karst is important to Floridians because Florida is almost entirely underlain by carbonate rocks. Karst is more than an academic problem when one considers that the surface of much of Florida's bedrock limestone probably resembles Figure 1, if one could strip off all overburden. Florida's karst means special problems which necessitate special considerations and precautions. Planners at all levels need to be familiar with karst, from the private citizen who plans to build a home to architects and engineers who design and site buildings and government officials who issue permits for construction or waste disposal. Florida's rapid population growth results in more construction of roads, houses, and other facilities, increased need for the safe disposal of all kinds of wastes, and increased demands on the State's water resources for consumptive and non-consumptive uses. All of these human activities place continually increasing stresses on the environment, which poses a need to understand Florida's karst. This publication will explore Florida karst: what causes it, specific examples of it, benefits and hazards associated with it, and what can be done about it.

METRIC CONVERSION FACTORS

The Florida Bureau of Geology, in order to prevent duplication of parenthetical conversions, inserts a tabular listing of conversion factors to obtain metric units.

MULTIPLY	*BY*	*TO OBTAIN*
feet	0.03048	meters
square feet	0.092	square meters
miles	1.609	kilometers
square miles	2.590	square kilometers
cubic feet	2.8311	cubic meters
gallons	3.785	liters
tons	0.907	metric tons

POROSITY AND PERMEABILITY

Karst formation involves primarily the chemical weathering and erosion of carbonate rocks. It is appropriate, therefore, to discuss factors relating to and controlling the movement of underground water. The two properties that are common to all rocks, and which control the movement of underground water, are porosity and permeability.

Porosity and permeability are intimately related. A porous rock con-

Figure 1. Karst limestone surface showing honeycomb of round solution pipes. This surface was exposed when the overburden was scraped off and the sands and clays plugging the pipes were removed by water jets. Bedrock is Ocala limestone of Eocene age in the abandoned Buda limerock mine off Route 41 between Newberry and High Springs. Picture taken about 1972 and used by permission of William A. Wisner, geologist, Florida Department of Transportation.

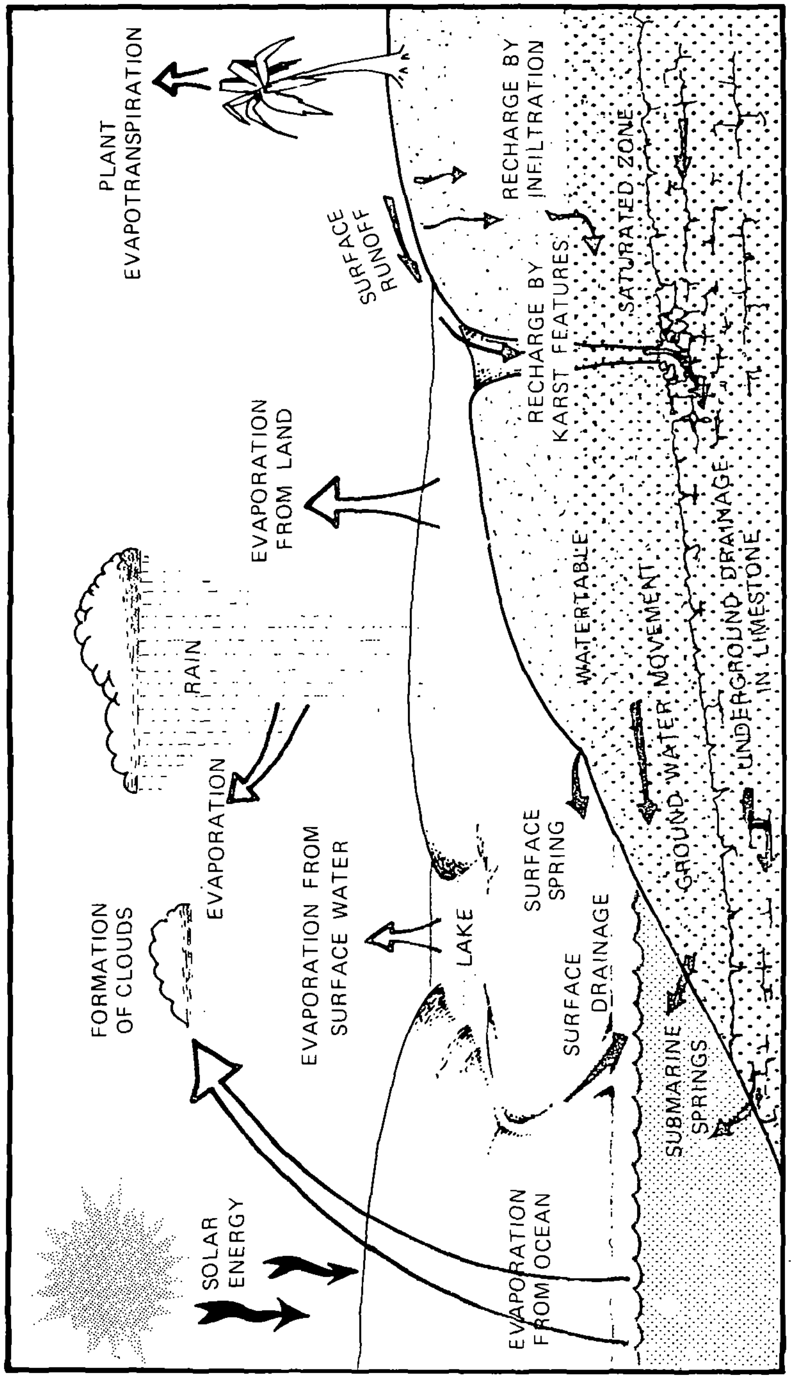

Figure 5. Hydrologic cycle: the constant movement of groundwater, surface and atmospheric waters. The diagram is highly simplified.

ward to recharge groundwater aquifers, then move laterally until being discharged to stream beds or in surface or submarine springs. Some underground water may be taken up by plants and evapotranspired to the atmosphere; some may be withdrawn by wells for human use.

All groundwater occurs in open spaces within the rock materials of the earth's crust. Aquifers are subsurface zones of rocks or sediments that yield water in sufficient quantities to be economically useful for man's activities. Aquifers are classified as either unconfined, semi-confined, or confined. Figure 6 illustrates several situations commonly encountered in Florida sediments and rocks.

Water that is in direct contact with the atmosphere through the pores or voids in sands, gravels, or rocks is called unconfined water, and the zone of sediments or rocks saturated with water is an unconfined aquifer, sometimes referred to as the surficial or watertable aquifer. The top of the watertable can be visualized as being the upper surface of the zone of saturation. The elevation of the watertable is also represented by the water level in wells. The watertable surface is usually a subdued replica of surface topography, with the watertable lying at shallow depths in much of Florida.

Semi-confined or confined water is separated from direct contact with the atmosphere by impermeable materials, such as clay beds or consolidated rocks. Confinement may impose pressures on the contained water that are higher than atmospheric, creating artesian conditions. Artesian conditions originally meant that a well produced flowing water at the surface because of the pressure in the penetrated aquifer. The term now refers to any condition where water is under greater-than-atmospheric pressure and will rise some distance up a well that penetrates a confined aquifer; however, the well need not flow at land surface.

In nature, the distinction between unconfined and confined groundwater is not so clear-cut, but is usually gradational due to the physical characteristics of most rocks. At one extreme are loose materials, such as sand, gravel, and many soils, which have relatively high permeabilities. At the other extreme are so-called tight, solid, or impermeable rocks or clays. While most clays, or sediments with significant amounts of clay, do have some permeability, it is usually so low that, for water-yielding purposes, they are classified as being "impermeable" and are considered to act as confining beds to more permeable rocks. Somewhere between these extremes lie countless combinations of rock types with varying degrees of permeability which are classified as semipermeable, i.e., *they may transmit enough water to allow recharge to contiguous strata, but they cannot provide useful quantities of water to a well.* Aquifers bounded by semipermeable units may be classified as semi-confined, depending on the water-yielding abilities of the rocks. Figure 6 illustrates this situation by showing surface water being recharged directly to the confined limestone aquifer through a sinkhole that has breached the confining bed, and indirect recharge of water from the

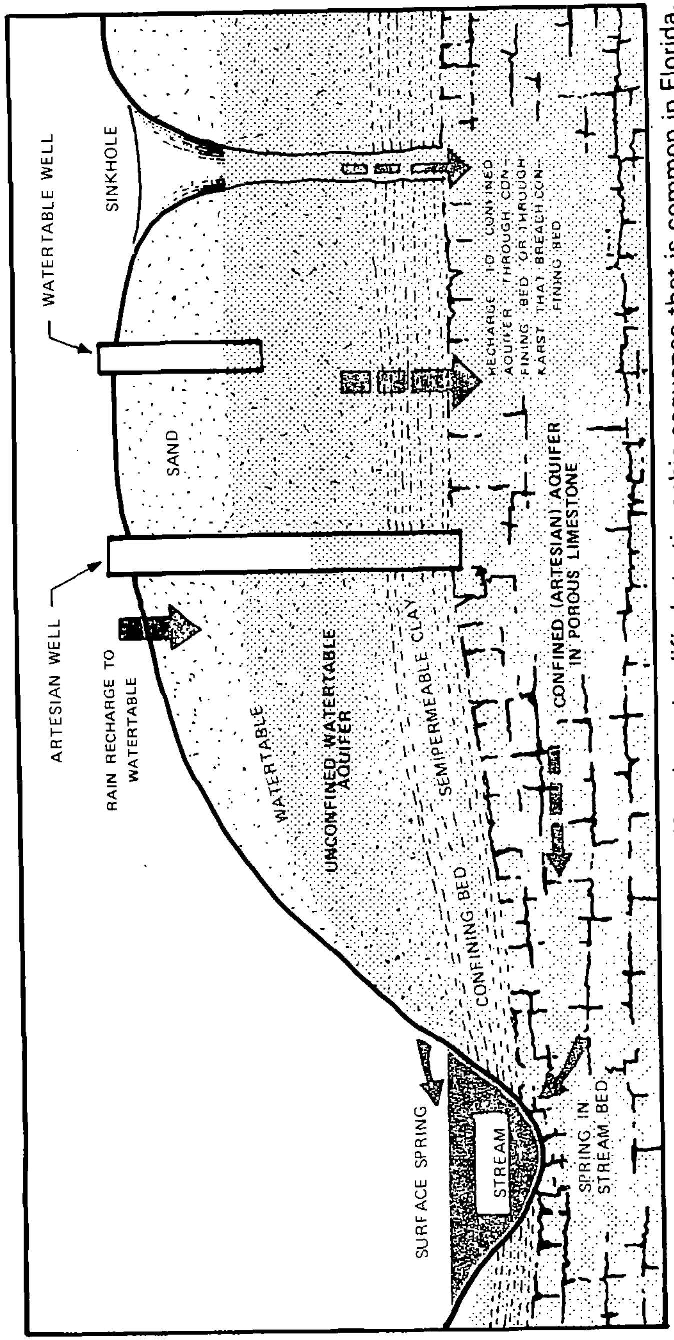

Figure 6. Unconfined and confined aquifers in a simplified stratigraphic sequence that is common in Florida. All materials below the watertable are saturated. Recharge to the watertable is by rain. Recharge to the confined aquifer is by water moving downward through the confining beds or through karst features that breach confining beds, such as sinkholes.

unconfined watertable aquifer by slow, downward seepage through the semi-permeable clay.

Unconfined and confined groundwaters move in response to gravity, the same as surface water, from higher to lower elevations. Confined groundwater also moves in response to pressure gradients, similar to the movement of water in pressurized pipes. As shown in Figure 6, water will migrate downward through the confining clay if the pressure created by the weight of the water in the overlying watertable aquifer is higher than the pressure in the confined aquifer. Conversely, if pressure in the confined aquifer were high enough to overcome the pressure of the water in the unconfined aquifer, then water would move from the limestone through the clay to the sand. Both of these situations commonly occur in Florida due to inhomogeneities of strata, karst features, and pressure gradients.

Springs are an expression of leakage from a watertable, semi-confined, or confined aquifer. In Figure 6, for example, the surface spring occurs because the watertable aquifer occurs on top of a confining bed that impedes the downward percolation of recharge water. This situation forces the water to move laterally, downslope, and discharge where the permeable sand and the less permeable clay bed intersect land surface. After prolonged periods of no rain the aquifer may become so depleted that the spring ceases to flow. This type of spring is frequently seen in the steep-walled stream valleys of north Florida.

Similarly in Figure 6, the subaqueous spring that discharges into the stream bed from the confined aquifer does so because of higher water pressure in the aquifer. In this situation, however, if the pressure in the aquifer falls too low due to depletion of water, the spring may reverse its flow, taking water back into the aquifer or recharging it. This, too, is a well-documented occurrence in some Florida streams. Ceryak, et al. (1983) found that many sinkholes in the bed of the Alapaha River near Jennings, in northwest Hami'ton County, Florida, have recharged as much as 770 cubic feet per second (497,420,000 gallons per day) to the adjacent aquifer. Miller, et al. (1978) found that, at times of high stages of the Suwannee River, river water was recharged to the limestone aquifer through karst features in its channel.

It is these driving forces in the hydrologic cycle that move underground water through Florida's carbonate rocks. In transit, the water dissolves and carries away in solution the chemical components of the rocks, leaving behind caves, solution pipes, and other voids that result in a karst terrain.

EVOLUTION OF KARST TERRAIN

The evolution of any terrain into characteristic landforms involves weathering and erosional processes: wind, water, frost heaving, slumping, or wave activity, to name a few. In most areas, the predominant

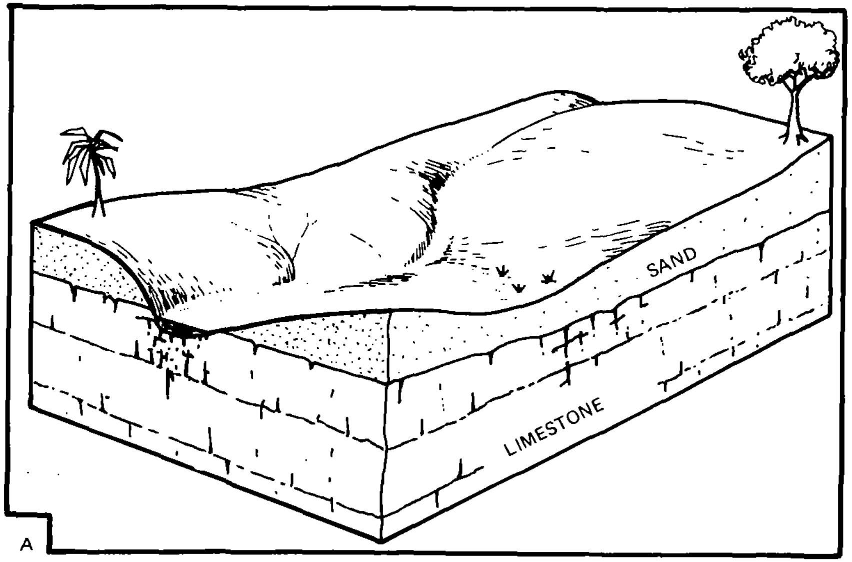

Figure 7a. Relatively young karst landscape showing underlying limestone beds and sandy overburden with normal, integrated surface drainage. Solution features are just beginning to develop in the limestone.

weathering, erosional, and transporting agent is water, either falling, flowing across the land, or circulating through subsurface rocks.

Chemical Weathering of Carbonate Rocks

Since the genesis of karst involves the development of underground drainage systems, it is necessary to study such systems to understand the formation of karst. Karst processes tend to be secretive and imperceptible because most development occurs underground over long periods of time. The results of these persistent processes will be manifested, sooner or later, in the subsidence of surficial sediments to form swales, the formation of a new sinkhole, a sudden influx of muddy water in a water-well after a heavy rain, or some other karst phenomenon that may disturb or disrupt man's activities. Figure 7 illustrates the evolution of karst terrain, as described below.

Chemical weathering is the predominant erosive process that forms karst terrain. Chemical weathering of limestone removes rock-mass through solution activity. As rain falls through the atmosphere, some carbon dioxide and nitrogen gases dissolve in it, forming a weak acidic solution. When the water comes into contact with decaying organic matter in the soil, it becomes more acidic. Upon contact with limestone,

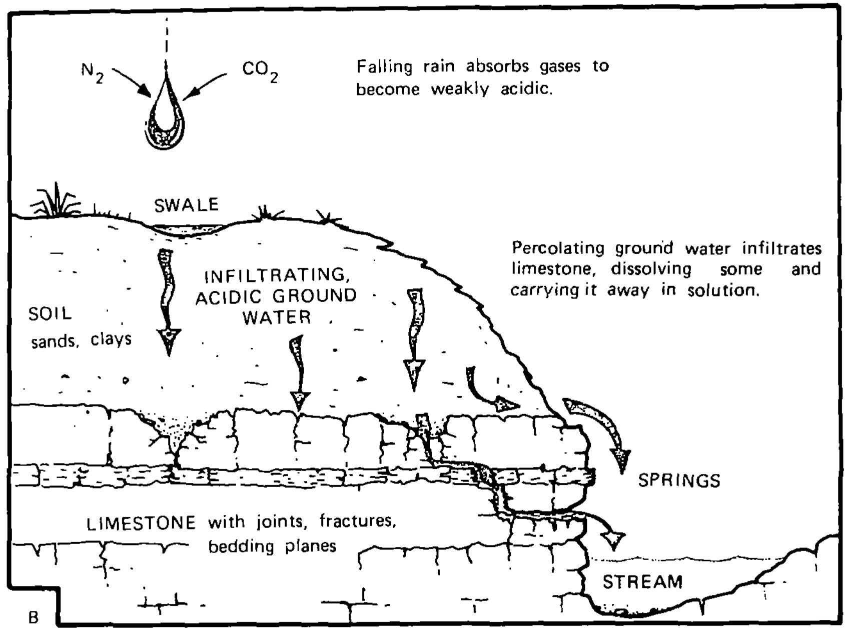

Figure 7b. Detail of Figure 7a showing early stages of karst formation. Limestone is relatively competent and uneroded. Chemical weathering is just beginning, with little internal circulation of water through the limestone. Swales, forming incipient sinkholes, act to concentrate recharge.

a chemical reaction takes place that dissolves some of the rock. All rocks and minerals are soluble in water to some extent, but limestone is especially susceptible to dissolution by acidic water. Limestones, by nature, tend to be fractured, jointed, laminated, and to have units of differing texture, all characteristics which, from the standpoint of percolating groundwater, are potential zones of weakness. These zones of weakness in the limestone are avenues of attack that, in time, the acidic waters will enlarge and extend. Given geologic time, conduits will permeate the rock that allow water to flow relatively unimpeded for long distances.

During the chemical process of dissolving the limestone, the water takes into solution some of the minerals. The water containing the dissolved minerals moves to some point of discharge, which may be a spring, a stream bed, the ocean, or a well, and another tiny volume of Florida's rock substrate has been removed.

Removal of the rock, with the continuing formation or enlargement of cavities, can ultimately lead to the collapse of overlying rocks or sediments. If the collapse is sudden and complete, an open sinkhole will

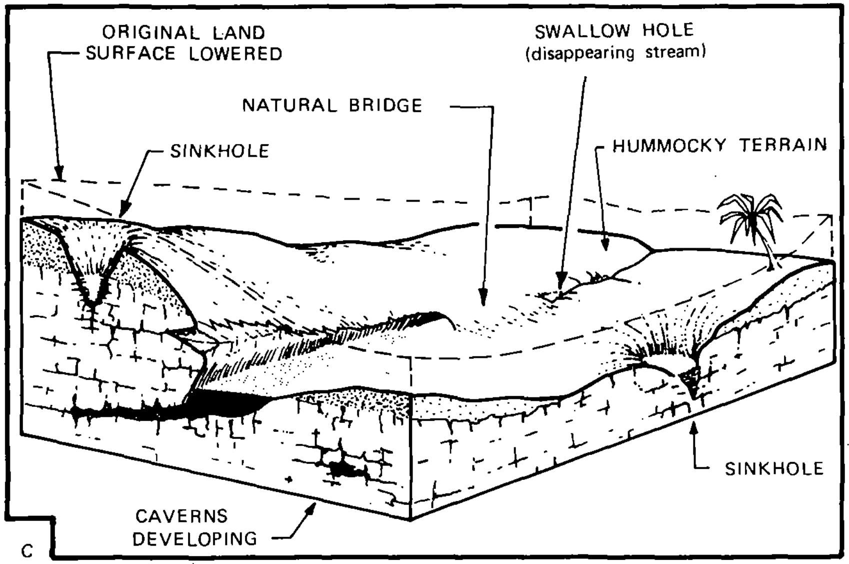

Figure 7c. Advanced karst landscape. Original surface has been lowered by solution and erosion. Only major streams flow in surface channels and they may cease to flow in dry seasons. Swales and sinkholes capture most of the surface water and shunt it to the underground drainage system. Cavernous zones are well-developed in the limestone.

result, sometimes revealing the cavity in the rock (Figures 8 and 9). More often, though, debris or water covers the entrance to subterranean drainage. Partial subsidence of the overburden into cavities will form swales at the surface, producing hummocky, undulating topography. By this slow, persistent process of dissolution of limestone and subsequent collapse of overburden, the land is worn down to form a karst terrain.

At some point in this process of dissolution of underground rocks, a normal surface drainage system will begin to be transformed into a dry or disappearing stream system. Continuing dissolution of the limestone will create more swales and sinkholes, which will divert more of the surface water into the underground drainage. Eventually, all of the surface drainage may by diverted underground, leaving dry stream channels that flow only during floods, or disappearing streams that flow down swallow holes (sinkholes in stream beds) and reappear at distant points to flow as springs or resurgent streams.

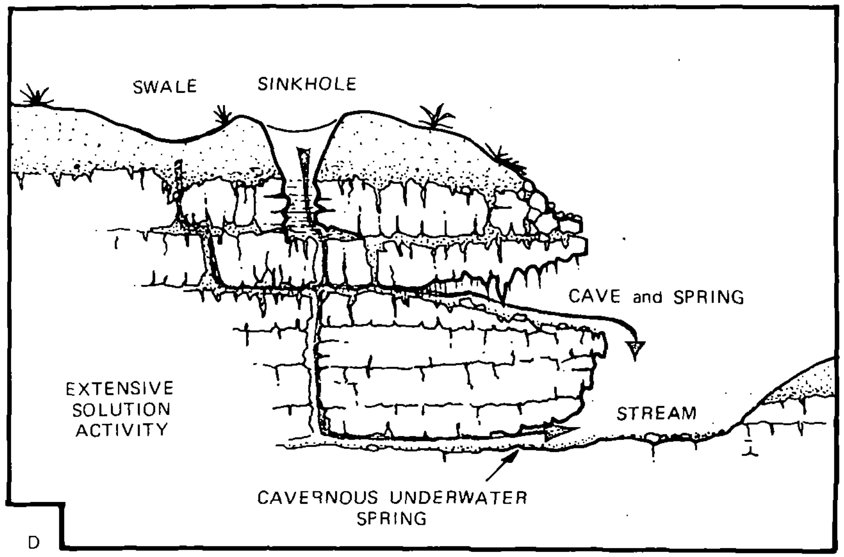

Figure 7d. Detail of Figure 7c showing advanced stage of karst formation. Limestone has well-developed interconnected passages that form an underground drainage system, which captures much or all of prior surface drainage. Overburden has collapsed into cavities forming swales or sinkholes. Caves may form. Land surface has been lowered due to loss of sand into the limestone's voids. Wakulla Springs and Silver Springs are examples of cavernous underwater springs.

Lowering of Land Surface

Inherent in the formation of karst terrain is the lowering of land surface on a regional scale, in contrast to the very localized lowering at a sinkhole. Regional lowering of the land surface takes place through the cumulative effects of thousands of individual, localized events, and through the continual removal of carbonate rock by dissolution. Several investigations have been made to determine an "average" rate of surface lowering in Florida, the results of which are discussed below and shown in Tables 1 and 2.

Table 1 gives comparative data for the ten largest first-magnitude springs in Florida. The amounts of solids removed from the land by these springs' flows range from 59 to 541 tons per day. These figures are impressive, but they do not indicate how rapidly the land surface may be being lowered. More meaningful are the amounts of material that are carried off per year per square mile of land surface, which can be calcu-

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In cooperation with
University of Florida,
Institute of Food and
Agricultural Sciences,
Agricultural Experiment
Stations and Soil Science
Department, and
Florida Department of
Agriculture and
Consumer Services

Soil Survey of Orange County, Florida

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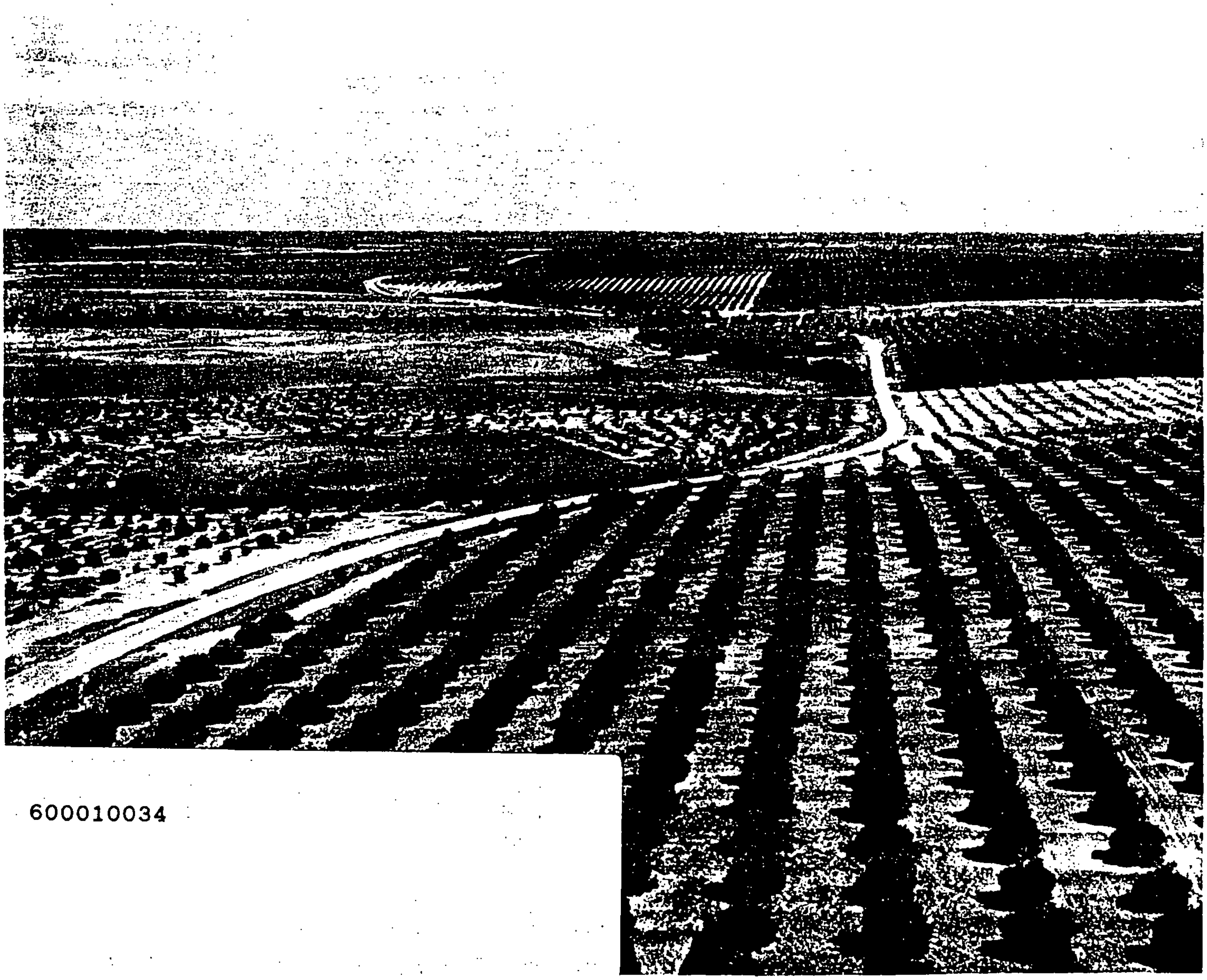


in slightly higher areas adjacent to the flatwoods. Scattered sinkholes and numerous lakes and ponds are in this map unit. These soils are extensive in the western half of Orange County on the Mount Dora Ridge, the Orlando Ridge, and Lake Wales Ridge and in scattered areas of the Osceola Plain. Tavares and Millhopper soils are nearly level to gently sloping and are moderately well drained. Tavares soils are on low ridges and knolls in upland areas. Millhopper soils are on low ridges and knolls on the flatwoods. Zolfo soils are nearly level and are somewhat poorly drained. They are in broad, slightly higher areas adjacent to the flatwoods.

The natural vegetation is bluejack oak, turkey oak, live oak, water oak, laurel oak, slash pine, and longleaf pine. The understory includes creeping bluestem, lopsided indiangrass, grassleaf goldaster, and pineland threeawn.

This map unit makes up about 12 percent of Orange County. It is about 37 percent Tavares soils and similar soils, 22 percent Zolfo soils and similar soils, 12 percent Millhopper soils and similar soils, and 29 percent soils of minor extent.

Typically, Tavares soils have a surface layer of very dark gray fine sand about 6 inches thick. The upper part of the underlying material, to a depth of about 16 inches, is brown fine sand. The middle part, to a depth of about 41 inches, is pale brown fine sand. The lower part to a depth of about 80 inches or more is white fine sand. Soils similar to Tavares soils are Archbold and Florahome soils.

Typically, Zolfo soils have a surface layer of dark grayish brown fine sand about 5 inches thick. The upper part of the subsurface layer, to a depth of about 23 inches, is grayish brown fine sand. The middle part, to a depth of 38 inches, is light brownish gray fine sand. The lower part, to a depth of about 55 inches, is very pale brown fine sand. The upper part of the subsoil, to a depth of about 71 inches, is brown fine sand. The lower part to a depth of about 80 inches or more is dark brown fine sand. Soils similar to Zolfo soils are Pomello soils that are moderately well drained.

Typically, Millhopper soils have a surface layer of dark grayish brown fine sand about 6 inches thick. The upper part of the subsurface layer, to a depth of about 42 inches, is light yellowish brown fine sand. The lower part, to a depth of about 66 inches, is very pale brown fine sand that has yellowish brown mottles. The upper part of the subsoil, to a depth of about 78 inches, is brownish yellow sandy loam. The lower part to a depth of about 80 inches or more is light gray sandy clay loam that has yellowish brown and yellowish red mottles. Soils similar to Millhopper soils are Apopka and Lochloosa soils.

Of minor extent in this map unit are Basinger, Candler, and Smyrna soils.

In most areas, the soils in this map unit are used for citrus crops (fig. 4) or pasture or for homesite and urban development. In some areas, these soils are used for cultivated crops.

4. Urban land-Tavares-Pomello

Nearly level to gently sloping, moderately well drained soils that are sandy throughout; some have an organic-stained subsoil at a depth of 30 to 50 inches; most areas have been modified for urban use

The soils in this map unit are on low ridges and knolls in the upland areas and on the flatwoods. A few short, steep slopes are near scattered sinkholes and numerous lakes, ponds, and wet areas. These soils are in the north-central part of Orange County on the Orlando Ridge. Several small areas of these soils are scattered on the Lake Wales Ridge and Osceola Plain in the western part of Orange County.

The existing natural vegetation is slash pine, bluejack oak, turkey oak, live oak, scattered sand pine, and longleaf pine. The understory includes saw palmetto, creeping bluestem, lopsided indiangrass, grassleaf goldaster, and pineland threeawn.

This map unit makes up about 6 percent of Orange County. It is about 40 percent Urban land, 26 percent Tavares soils and similar soils, 16 percent Pomello soils and similar soils, and 18 percent soils of minor extent.

The Urban land part of this complex is covered by concrete, asphalt, buildings, or other impervious surfaces that obscure or alter the soils so that their identification is not feasible.

Typically, Tavares soils have a surface layer of dark gray fine sand about 6 inches thick. The upper part of the underlying material, to a depth of about 10 inches, is grayish brown fine sand. The middle part, to a depth of about 48 inches, is pale brown fine sand. The lower part to a depth of about 80 inches is very pale brown fine sand. Soils similar to Tavares soils are Florahome and Seffner soils.

Typically, Pomello soils have a surface layer of dark gray fine sand about 5 inches thick. The subsurface layer, to a depth of about 42 inches, is white fine sand. The upper part of the subsoil, to a depth of about 48 inches, is dark reddish brown fine sand. The lower part, to a depth of about 54 inches, is dark brown fine sand. The substratum to a depth of about 80 inches is light gray fine sand. Soils similar to Pomello soils are Zolfo soils.

Of minor extent are Archbold, Basinger, Candler, Lochloosa, Millhopper, and Smyrna soils.

Most of the acreage in this map unit is used for houses, large buildings, shopping centers, golf courses, and related urban uses. Natural vegetation thrives only in a few areas in this map unit. Farming is of little importance because of the extensive urban development. Numerous nurseries produce plants for landscaping. Part of the cities of Orlando, Maitland, and Ocoee have been developed on these soils.

managed. The water control system should maintain the water table near the surface to prevent excess subsidence of the organic material. Regular applications of fertilizer and lime are needed. Grazing should be controlled to maintain plant vigor.

This soil is not suited to pine trees.

This soil has severe limitations for building site development, sanitary facilities, and recreational uses because of ponding and excess humus. Water control measures should be used to minimize the excessive wetness limitation. Organic material, which has low soil strength, should be removed and backfilled with a soil material suitable for urban use. Constructing buildings on pilings can help prevent structural damage that is caused by soil subsidence. The sealing or lining of a sewage lagoon or trench sanitary landfill with impervious soil material can reduce excessive seepage. The sidewalls of shallow excavations should be shored. Water control measures should be used to minimize the excessive wetness limitation. Mounding of septic tank absorption fields may be needed.

This Terra Ceia soil is in capability subclass IIIw and has not been assigned to a woodland group.

50—Urban land. This miscellaneous area is covered by such urban facilities as shopping centers, parking lots, industrial buildings, houses, streets, sidewalks, airports, and related urban structures. The natural soil cannot be observed. The slopes are dominantly less than 2 percent but range to 5 percent.

In areas mapped as Urban land, 85 percent or more of the surface is covered by asphalt, concrete, buildings, and other impervious surfaces that obscure or alter the soils so that their identification is not feasible.

Included in this map unit are moderately urbanized areas where structures cover 50 to 85 percent of the surface. Candler, Florahome, Millhopper, Ona, Pomello, St. Lucie, Smyrna, Tavares, and Wabasso soils mostly are used for lawns, playgrounds, parks, and open areas. These soils generally have been altered by grading and shaping or have been covered by about 12 inches of fill material. This fill material consists of sandy and loamy material that may contain fragments of limestone and shell. The individual areas of soils in this map unit are too small to map separately at the scale used for the maps in the back of this publication.

Drainage systems have been established in most areas of Urban land. Depth to the seasonal high water table is dependent upon the functioning of the drainage system.

Urban land has not been assigned to a capability subclass or to a woodland group.

51—Wabasso fine sand. This soil is nearly level and poorly drained. It is on broad flatwoods. The slopes are smooth to slightly convex and range from 0 to 2 percent.

In 90 percent of areas mapped as Wabasso fine sand, Wabasso soil and similar soils make up 96 to 99 percent of the mapped areas. Dissimilar soils make up 1 to 4 percent of the mapped areas.

Typically, this soil has a surface layer of black fine sand about 3 inches thick. The subsurface layer, to a depth of about 18 inches, is light brownish gray fine sand. The upper part of the subsoil, to a depth of about 21 inches, is black fine sand. The middle part, to a depth of about 45 inches, is very pale brown sandy clay loam that has common yellowish brown mottles. The lower part, to a depth of 70 inches, is light gray sandy clay loam that has common yellowish brown mottles. The substratum to a depth of 80 inches or more is light brownish gray loamy sand. In the mapped areas are similar soils, but some of these soils have a subsoil at a depth of 30 inches, in some soils the lower part of the subsoil is at a depth of more than 40 inches, and in some the upper part of the subsoil is weakly coated with colloidal organic matter.

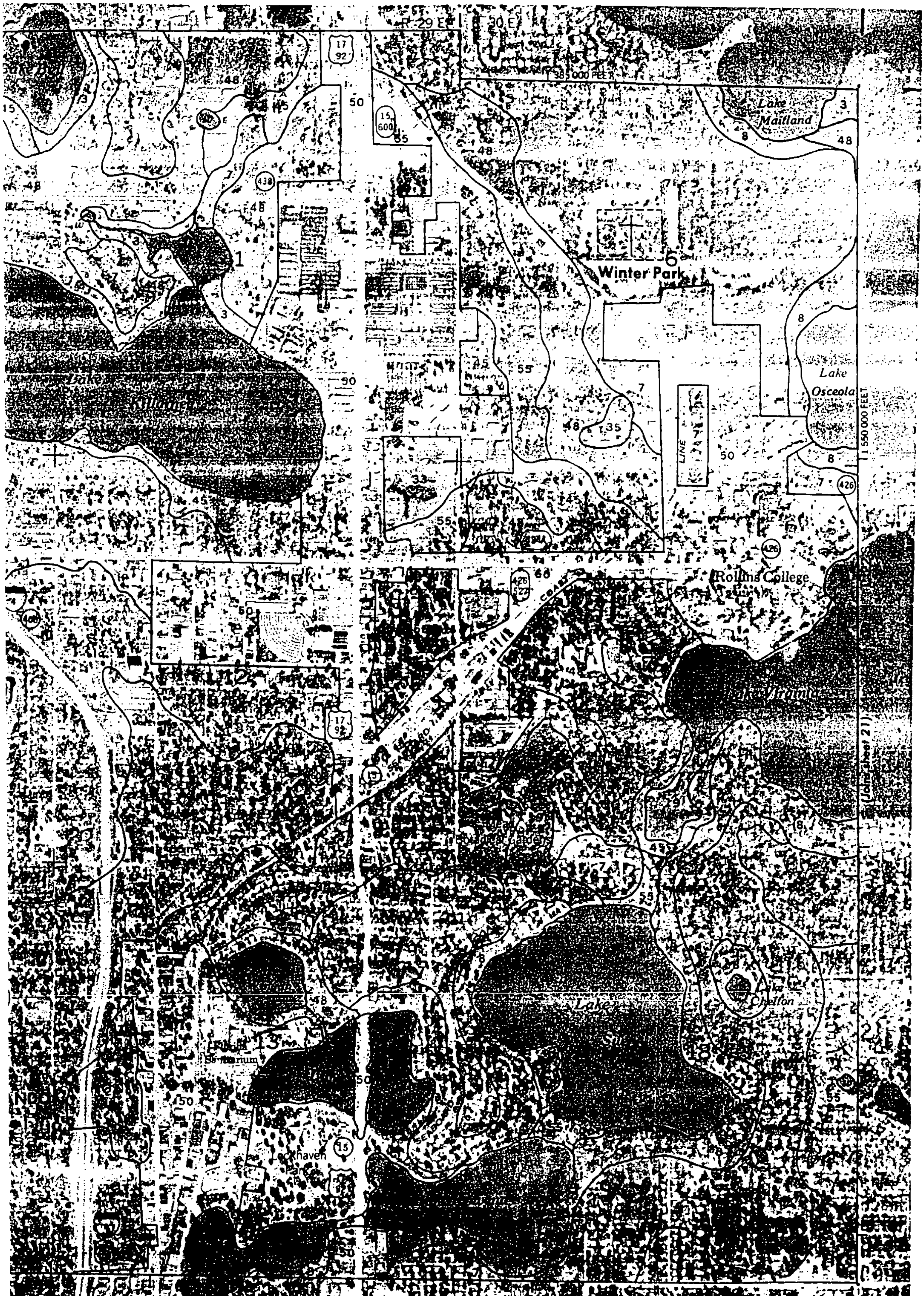
Dissimilar soils included in mapping are Immokalee and Smyrna soils in small areas.

In most years, a seasonal high water table is at a depth of less than 10 inches for 1 month to 5 months. It recedes to a depth of more than 40 inches during extended dry periods. The permeability is rapid in the surface and subsurface layers and in the substratum. It is moderate in the sandy part of the subsoil and slow or very slow in the loamy part. The available water capacity is very low in the surface and subsurface layers, medium in the subsoil, and low in the substratum. Natural fertility is low. The organic matter content is moderate to moderately low.

In most areas, this Wabasso soil has been left in natural vegetation. In a few areas, it is used for cultivated crops, improved pasture, or citrus crops or for homesite and urban development. The natural vegetation is longleaf pine and slash pine. The understory includes lopsided indiangrass, inkberry, saw palmetto, pineland threeawn, waxmyrtle, bluestem, panicum, and other grasses.

This soil has very severe limitations for cultivated crops because of wetness and the sandy texture in the root zone. However, if a water control system is installed and soil-improving measures are used, this soil is fairly suited to many vegetable crops. A water control system is needed to remove excess water in wet periods and to provide for subsurface irrigation in dry periods. Soil-improving crops and crop residue should be used to control erosion and to maintain the content of organic matter in the soil. Seedbed preparation should include the bedding of rows. Fertilizer and lime should be applied according to the need of the crop.

The suitability of this soil for citrus trees is good in areas that are relatively free of freezing temperatures and if a water control system is installed to maintain the water table at a depth of about 4 feet. Planting trees on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Winter Park
Lake Osceola
Rollins College
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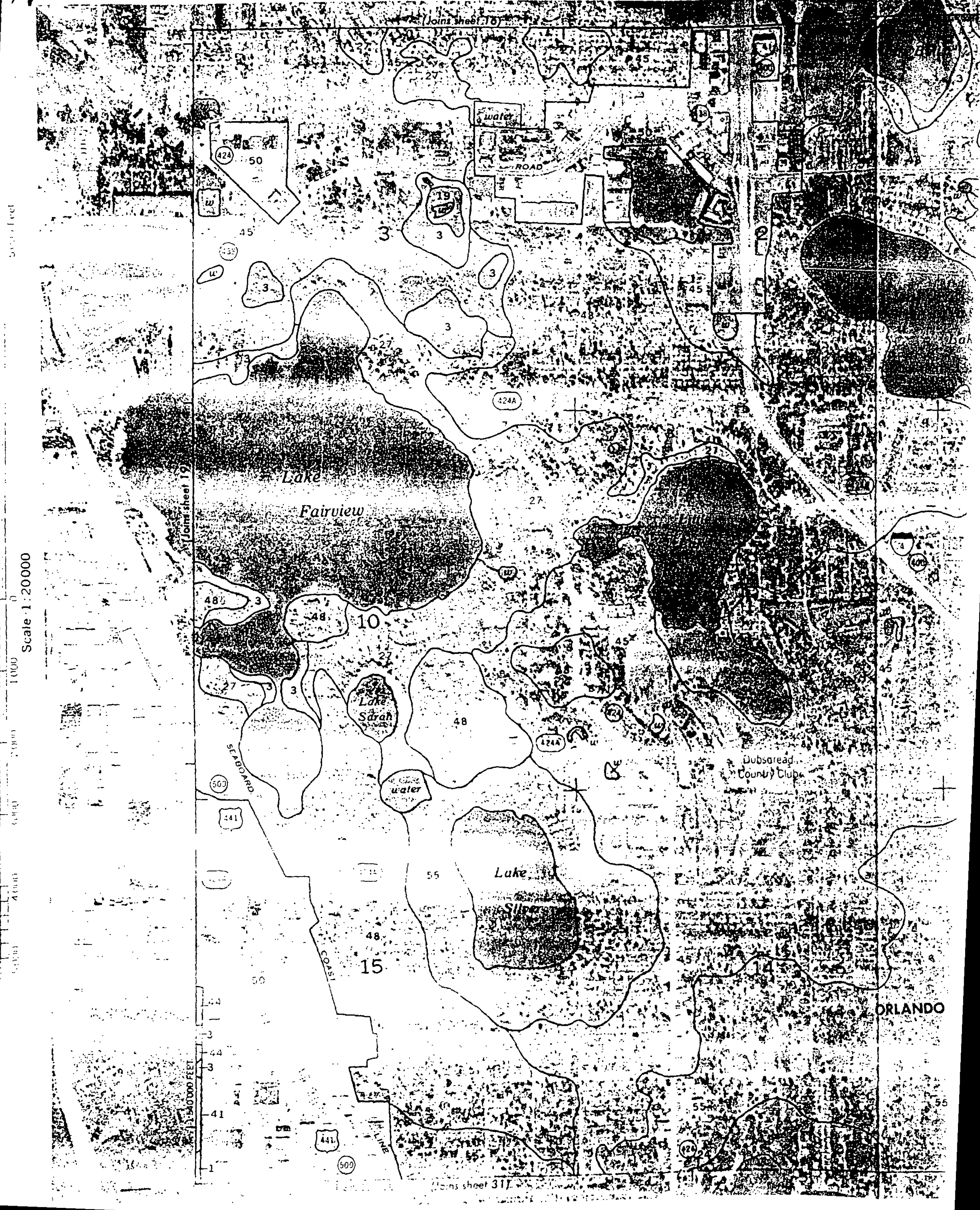
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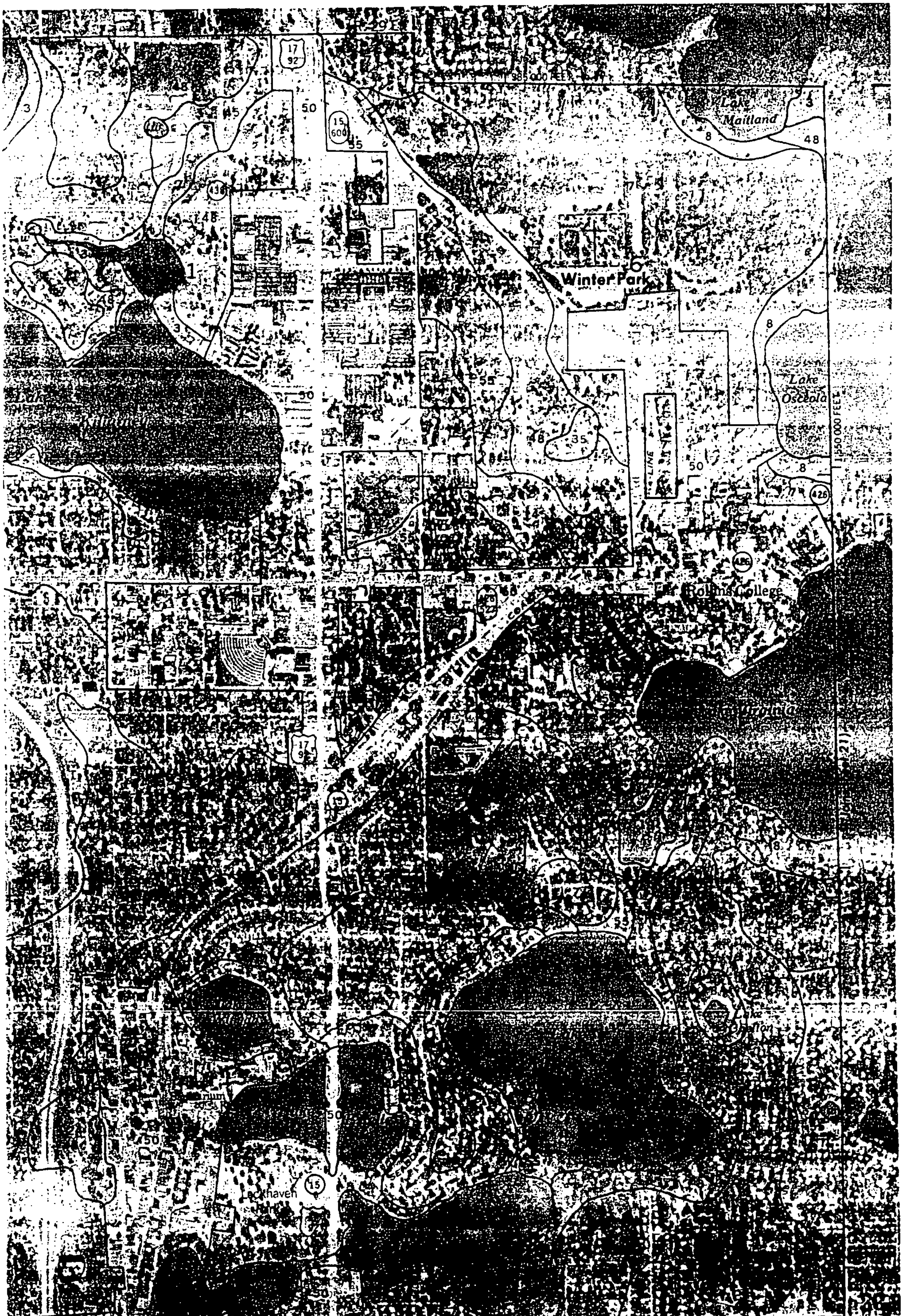

REFERENCE 12

STATE OF FLORIDA
DEPARTMENT OF NATURAL RESOURCES
Tom Gardner, *Executive Director*

DIVISION OF RESOURCE MANAGEMENT
Jeremy A. Craft, *Director*

FLORIDA GEOLOGICAL SURVEY
Walter Schmidt, *State Geologist*

BULLETIN NO. 59

THE LITHOSTRATIGRAPHY OF THE HAWTHORN GROUP (MIOCENE) OF FLORIDA

By
Thomas M. Scott

Published for the
FLORIDA GEOLOGICAL SURVEY
TALLAHASSEE
1988

DEPARTMENT
OF
NATURAL RESOURCES

DEPARTMENT
OF
NATURAL RESOURCES

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Governor

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Executive Director

LETTER OF TRANSMITTAL

Bureau of Geology
August 1988

Governor Bob Martinez, Chairman
Florida Department of Natural Resources
Tallahassee, Florida 32301

Dear Governor Martinez:

The Florida Geological Survey, Bureau of Geology, Division of Resource Management, Department of Natural Resources, is publishing as its Bulletin No. 59, *The Lithostratigraphy of the Hawthorn Group (Miocene) of Florida*. This is the culmination of a study of the Hawthorn sediments which exist throughout much of Florida. The Hawthorn Group is of great importance to the state since it constitutes the confining unit over the Floridan aquifer system. It is also of economic importance to the state due to its inclusion of major phosphorite deposits. This publication will be an important reference for future geological investigations in Florida.

Respectfully yours,

Walter Schmidt, Chief
Florida Geological Survey

TABLE OF CONTENTS

APPENDIX

FIGURES

TABLE

ABSTRACT

The Hawthorn Formation has been a problematic unit for geologists since its inception by Dall and Harris (1892). It is a complex unit consisting of interbedded and intermixed carbonate and siliciclastic sediments containing varying percentages of phosphate grains. These sediments have been widely studied by geologists due to their economic and hydrologic importance in the southeastern United States. Economically, the Hawthorn sediments contain vast quantities of phosphate and clay and limited amounts of uranium. Hydrologically, the Hawthorn contains secondary artesian aquifers, provides an aquiclude for the Floridan aquifer system and, in some ares, makes up the upper portion of the Floridan aquifer system.

The Hawthorn Formation of previous investigators has been raised to group status in Georgia by Huddlestun (in press). The present investigation extends the formations recognized in southern Georgia into northern Florida with some modifications, and accepts Huddlestun's concept of the Hawthorn Group. The Hawthorn Group and its component formations in southern Florida represent a new lithostratigraphic nomenclature applied to these sediments. The elevation of the Hawthorn to group status in Florida is justified by the Hawthorn's complex nature and the presence of areally extensive, mappable lithologic units.

The Hawthorn Group in northern peninsular Florida consists of, in ascending order, the Penney Farms Formation, the Marks Head Formation and the Coosawhatchie Formation. The Coosawhatchie Formation grades laterally and, in a limited area, upwards into the Statenville Formation.

Lithologically, the Hawthorn Group in northern Florida is made up of a basal carbonate with interbedded siliciclastics (Penney Farms), a complexly interbedded siliciclastic-carbonate sequence (Marks Head), a siliciclastic unit with varying percentages of carbonate in both the matrix and individual beds (Coosawhatchie) and a crossbedded, predominantly siliciclastic unit (Statenville). Phosphate grains are present throughout these sediments, varying in percentage up to 50 percent of the rock.

Sediments of the Hawthorn Group in northern peninsular Florida range in age from Early Miocene (Aquitanian) to Middle Miocene (Serravalian). This represents a significant extension of the previously accepted Middle Miocene age.

In southern Florida, the group includes two formations, in ascending order, the Arcadia Formation and the Peace River Formation. The Tampa Formation or Limestone of former usage is included as a lower member of the Arcadia Formation due to the Tampa's limited areal extent, lithologic similarities, and lateral relationship with the undifferentiated Arcadia. Similarly, the Bone Valley Formation of former usage is incorporated as a member in the Peace River Formation.

Lithologically, the Arcadia Formation is composed of carbonate with varying amounts of included and interbedded siliciclastics. Siliciclastic sediments in the Arcadia are most prevalant in its basal Nocatee Member. The Peace River Formation is predominantly a siliciclastic unit with some interbedded carbonates. Phosphorite gravel is most common in the Bone Valley Member. Sand-sized phosphate grains are virtually ubiquitous in the southern Florida sediments with the exception of the Tampa Member where it is often absent.

The southern Florida Hawthorn sediments range in age from Early Miocene (Aquitanian) to Early Pliocene (Zanclian).

The Hawthorn Group in the eastern Florida panhandle is composed of the Torreya Formation and, in a few areas, a Middle (?) Miocene unnamed siliciclastic unit. Lithologically, the Torreya consists of a carbonate-rich basal section with interbedded clays and sands, and a dominantly siliciclastic, often massive, plastic clayey upper unit (Dogtown Member). Phosphate grains are noticeably less common in the Hawthorn of the panhandle.

Hawthorn Group sediments are characterized by the occurrence of an unusual suite of minerals. Apatite (phosphate grains) is virtually ubiquitous in the peninsular Hawthorn sediments. Palygorskite, sepiolite and dolomite occur throughout the group statewide.

Miocene sea level fluctuations were the primary controlling factor determining the extent of Hawthorn deposition in Florida. During the maximum Miocene transgression, sediments of the Hawthorn Group

were probably deposited over the entire Florida platform. Hawthorn sediments were subsequently removed from the crest of the Ocala Platform (Ocala Uplift) and the Sanford High by erosion.

The Hawthorn Group appears to have been deposited under shallow marine conditions. These conditions are suggested by the occurrence of molds of shallow water mollusks and a limited benthic foraminifera fauna. The deepest water conditions apparently existed in the Jacksonville and Okeechobee Basins.

The gamma-ray signature of the Hawthorn Group is quite distinctive, providing a useful tool for identification and correlation in areas of limited data. The Hawthorn signature consists of distinctly different patterns in northern and southern peninsular and eastern panhandle Florida.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance of many individuals during the course of this study. The assistance of these individuals was invaluable in the successful completion of this investigation.

The author thanks C.W. "Bud" Hendry, Jr., former State Geologist of Florida, and Steve Windham, former Bureau Chief of the Florida Bureau of Geology for allowing the author to attend Florida State University under the state's job related courses program. Discussions and support from the staff of the Florida Geological Survey were greatly appreciated. Of particular assistance were Ken Campbell, Paulette Bond and Walt Schmidt, State Geologist. Justin Hodges, former driller for the Florida Geological Survey, was invaluable to this study. Mr. Hodges' expertise was responsible for the recovery of excellent quality cores, many of which were used in this research. Draftsmen Jim Jones and Ted Kiper spent many hours laboring over the figures for the text.

Thanks are due to a number of individuals around the state for their help during this project. These include: Jim Lavender, Tony Gilboy, Jim Clayton, John Decker, Greg Henderson and Kim Preedom of the Southwest Florida Water Management District who provided cores and geophysical data; Mike "50-50" Knapp from the South Florida Water Management District; Drs. Sam Upchurch and Richard Strom of the University of South Florida; and to Tom Missimer of Missimer and Associates.

Special thanks are due to Dr. Paul Huddlestun of the Georgia Geologic Survey for many hours of discussion and data sharing. Muriel Hunter also shared freely her knowledge of Florida stratigraphy.

The author is very appreciative of the very competent assistance of Cindy Collier, secretary from the Geological Investigations Section of the Florida Geological Survey. The final form of this manuscript would have been significantly more difficult to achieve without her assistance.

The author greatly appreciates the guidance and assistance of his faculty committee, Drs. Sherwood Wise (Chairman), William Parker, J.K. Osmond, Steve Winters, and William Burnett. Their time and effort assisted in an improved final draft. The author also appreciates the many hours of discussion and the assistance provided by former FSU graduate students and Florida Geological Survey graduate assistants Andy LeRoy and Barry Reik.

Reviews of this manuscript by a number of geologists aided the author in presenting this study in a more concise manner. This author greatly appreciates the efforts of the following reviewers: Walt Schmidt, Bill Yon, Ken Campbell, Ed Lane, Jackie Lloyd, Paulette Bond and Alison Lewis of the Florida Geological Survey; Drs. Wise, Parker, Osmond, Winters, and Burnett of Florida State University; Dr. Sam Upchurch of the University of South Florida; and Ms. Muriel Hunter, independent geologist.

Finally, and most importantly, are the thanks due to my family for their support during this endeavor. My wife of 17 years has lived with this research for more than one third of our married life. This research would not have been completed without her support.

THE LITHOSTRATIGRAPHY OF THE HAWTHORN GROUP (MIOCENE) OF FLORIDA

By
Thomas M. Scott

INTRODUCTION

The late Tertiary (Miocene-Pliocene) stratigraphy of the southeastern Coastal Plain provides geologists with many interesting and challenging problems. Much of the interest has been generated by the occurrence of scattered phosphorite from North Carolina to Florida. The existence of phosphate in the late Tertiary rocks of Florida was recognized in the late 1800's and provided an impetus to investigate these sediments. More recently, the hydrologic importance of these units has led to further investigations of the stratigraphy and lithology to determine their effectiveness as an aquiclude, aquitard and aquifer.

The Hawthorn Formation in Florida has long been a problematic unit. Geologists often disagree about the boundaries of the formation. The resulting inconsistencies have rendered accurate correlation between authors virtually impossible.

The biggest problem hindering the investigation of the Hawthorn strata has been a paucity of quality subsurface data. Since the mid-1960's, the Florida Geological Survey has been gathering core data from much of the state, providing a unique opportunity to investigate the extent of, and facies relationships in the Hawthorn of the subsurface.

This investigation is an attempt to provide an understanding of the Hawthorn Group, its lithologies, stratigraphy and relation to subjacent and suprajacent units. A greater understanding of the Hawthorn is imperative to deciphering the late Tertiary geologic history of Florida.

PURPOSE AND SCOPE

The purpose of this investigation is to provide a coherent lithostratigraphic framework facilitating a better understanding of the Hawthorn Group in Florida. The internal framework of the Hawthorn, its lateral continuity, and relation to subjacent and suprajacent units were investigated in order to provide this knowledge.

The area covered by this study extends from the Apalachicola River in the Florida Panhandle on the west to the Atlantic Coast on the east and from the Georgia-Florida border on the north, south to the Florida Keys (Figure 1). The study area encompasses all or portions of 56 counties. Data points outside the study area, particularly in Georgia, were used to assist in providing a more accurate picture within the study area boundaries.

The study area boundaries were chosen based on several criteria. In the past, the western limits of the Hawthorn were drawn at the Apalachicola River. The western boundary was chosen both to coincide with the historical boundary and to avoid overlap with the investigation of equivalent sediments in the Apalachicola Embayment by Schmidt (1984).

More than 100 cores provided the data base for the present study. The locations of cored data points are shown on Figure 2. Figure 3 delineates cross section transects.

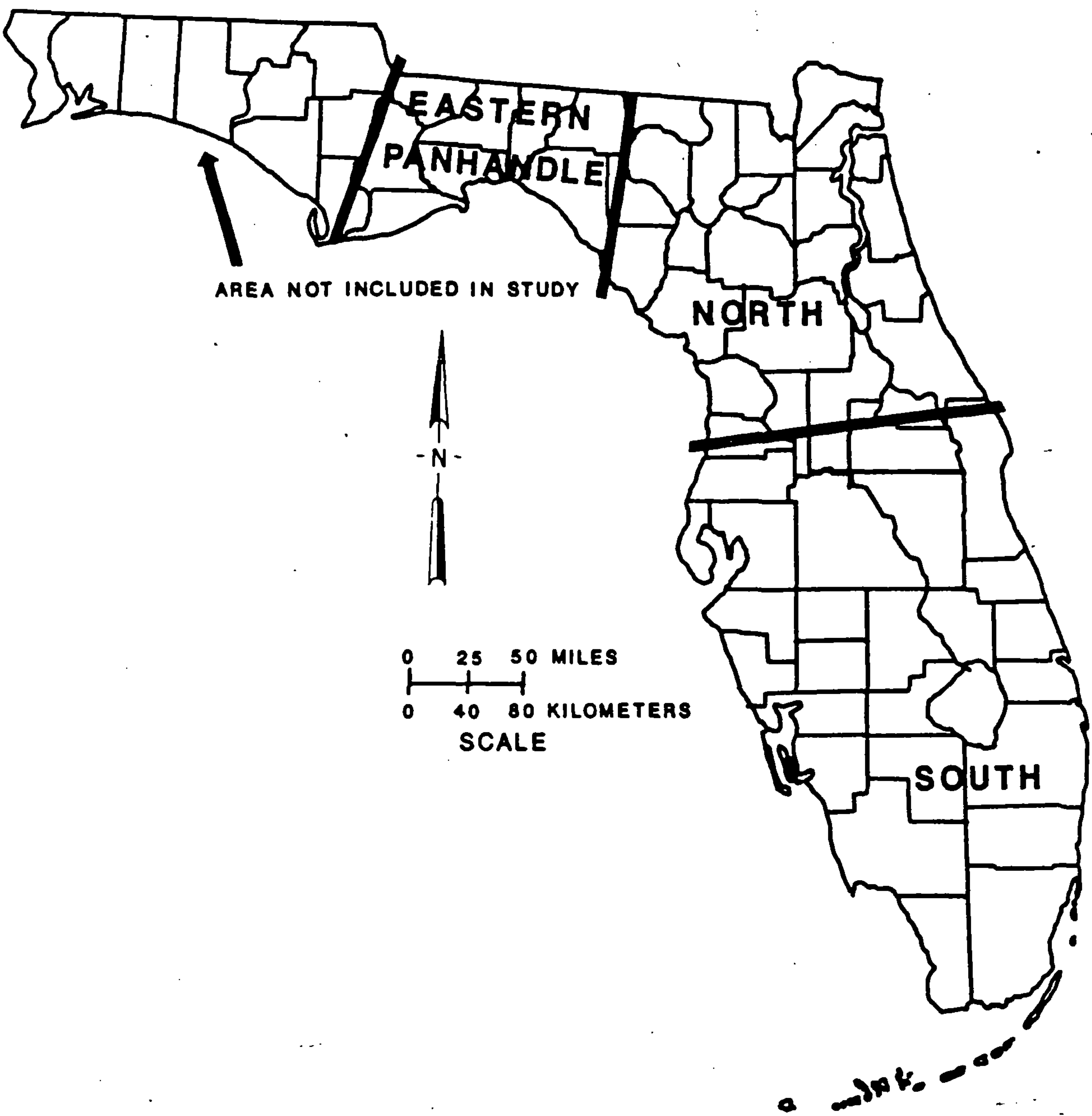


Figure 1. Study area and areas of discussion.

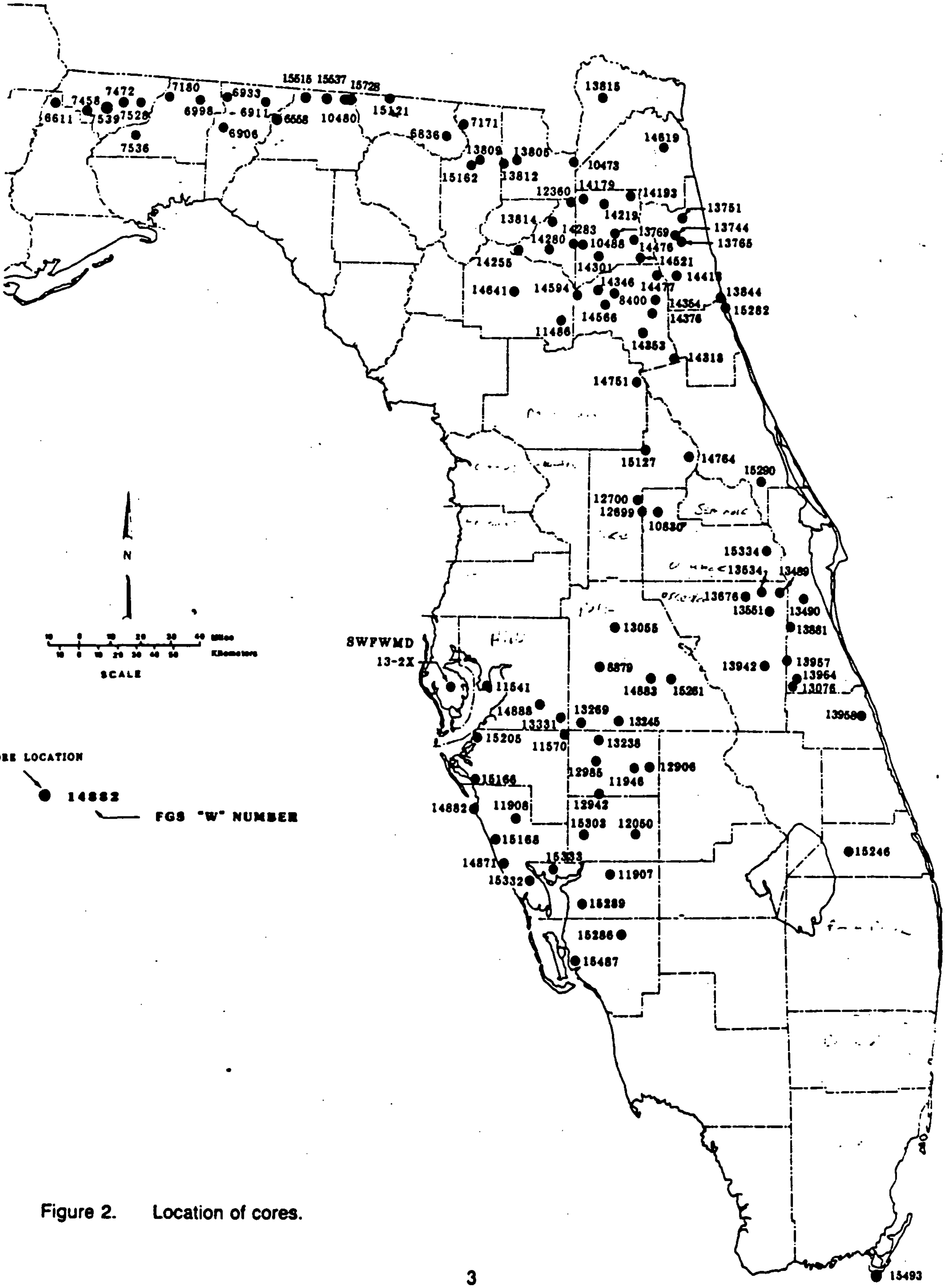


Figure 2. Location of cores.

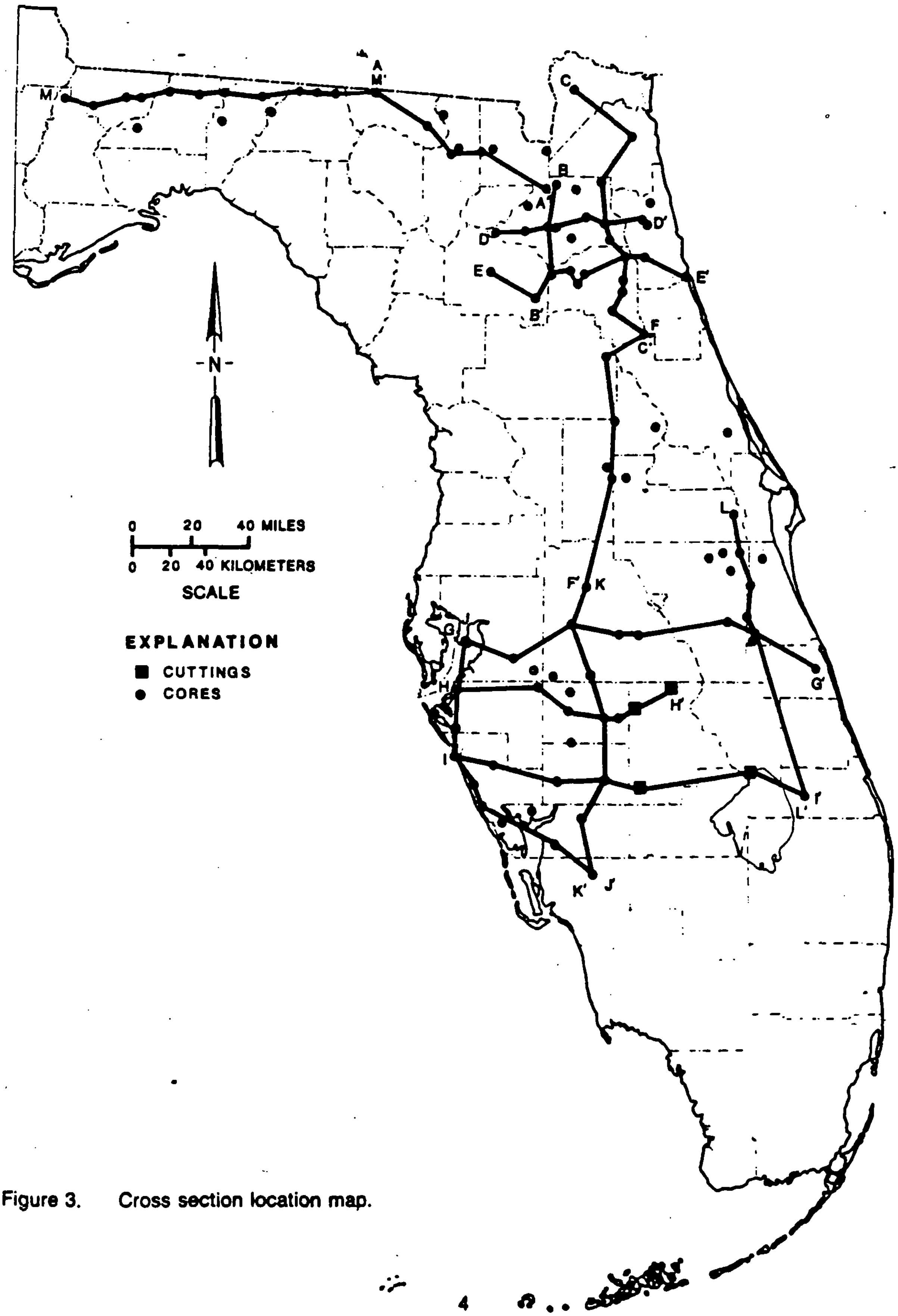


Figure 3. Cross section location map.

METHOD OF INVESTIGATION

The Hawthorn Group is predominantly a subsurface unit. As a result, the principal data sources for this study were the cores drilled by the Florida Geological Survey from 1964 through the present. The cores were obtained using a Failing 1500 Drillmaster with a capacity to drill in excess of 1000 feet (305 meters). Under most conditions, nearly continuous recovery of 1-¾ inch (4.5 cm) diameter cores was obtained. Losses in core recovery were minimized due to the expertise of driller Justin Hodges. The cores recovered were placed in boxes and are stored at the Geological Survey in Tallahassee. Additional cores were obtained from the Southwest Florida Water Management District and the St. Johns River Water Management District. All cores are available for inspection by the public.

Supplemental lithologic data sources included samples obtained from water wells drilled by private contractors who provide cuttings to the Geological Survey. Unfortunately, the cuttings do not necessarily provide accurate lithologic information. This circumstance is due to the loss of fine grained (clay, silt and very fine sand-sized), poorly consolidated to nonindurated sediments. The drilling method, sample collection, and subsequent removal of drill mud by washing facilitates the loss of this material. The net result is to skew the sediment types toward sands and more indurated materials. The use of cuttings does, however, allow the extrapolation of lithologies and contacts in areas of limited core control. Water-well cuttings were thus used only to supplement core data.

All cores and well cuttings were examined using a binocular microscope. Examinations were normally made at magnification of 10x to approximate the use of a hand lens in field indentification. Higher magnifications (up to 45x) were employed for the identification of the finer grained constituents of the sediments. Geologist's logs of the samples were recorded according to the Florida Geological Survey format which aids in producing a concise, standardized lithologic description. Coded lithologic data were stored on magnetic tape for later retrieval and use. These data were run through the Florida Geological Survey's FBGO1 program on the Florida State University computer which provided a full English printout of the lithologic information. The data were also run through the Stratlog program to provide a lithologic column of each core analyzed.

Samples collected for x-ray analysis were taken primarily from cores, although outcrops along the Suwannee and Alapaha Rivers were also sampled. Since clay minerals present in the sediments were of primary interest, samples were taken from the more clayey portions of the cores. Samples were mounted for x-ray analysis by standard techniques and analyzed with CuKα radiation.

Gamma-ray logs were run on most core holes. Numerous gamma-ray logs run in water wells are also available for correlation purposes. All geophysical logs are on permanent file at the Geological Survey and are open to the public.

PREVIOUS INVESTIGATIONS

Interest in the general stratigraphic framework of the southeastern Coastal Plain and the occurrence of phosphate in the sediments now assigned to the Hawthorn Group prompted geologists to investigate these sediments in Florida. Table 1 indicates the important nomenclatural changes that have occurred in relation to the Hawthorn Group.

The discovery of phosphatic rock in Florida first occurred in the late 1870's near the town of Hawthorne in Alachua County (Day, 1886). By 1883, Dr. C.A. Simmons quarried and ground the phosphatic rocks for fertilizer (Sellards, 1910). During the 1880's phosphate was also discovered in central Florida.

Smith (1881) noted the phosphatic rocks exposed along the Suwannee River from the Okefenokee Swamp downstream and placed them in the Vicksburg Stage. Hawes (1882), in discussing the "phosphatic sandstones from Hawthorne," described them as containing sharks' teeth and bones belonging to the Tertiary Age. Smith (1885) and Johnson (1885) discussed the stratigraphy and occurrence of the phosphatic rocks of Florida. Johnson (1885) applied the name Fort Harlee marl to the phosphatic sediments at Waldo in Alachua County. He mentioned the occurrence of *Ostrea* and silicified corals within the sediments. Johnson also mentioned that those rocks are rather widespread in the state.

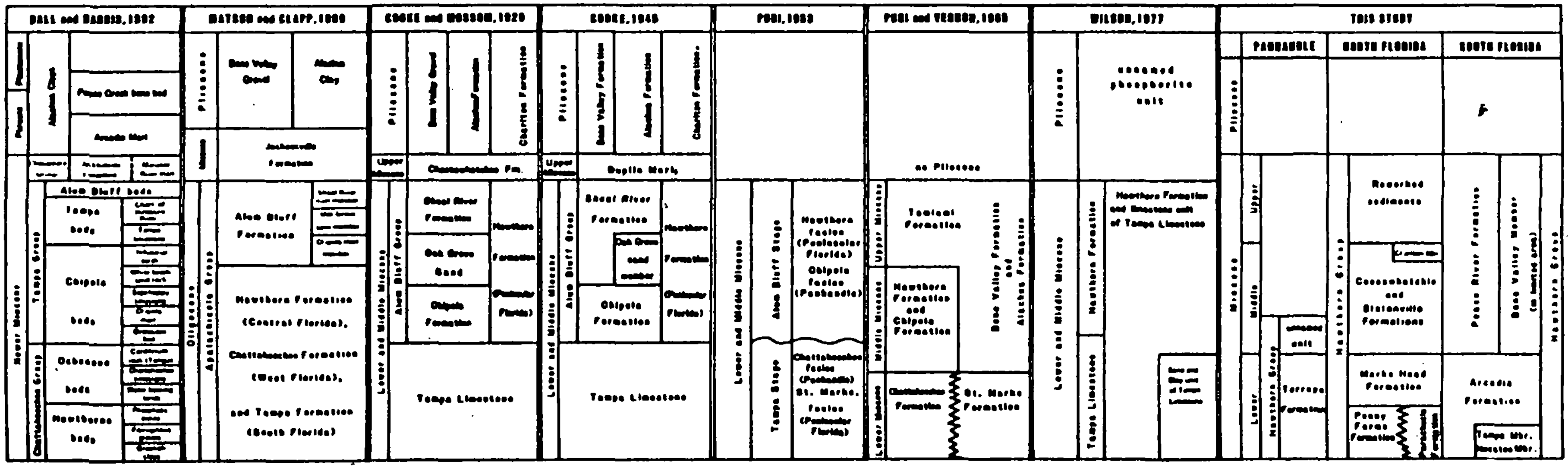


Table 1. Nomenclatural changes that have occurred in relation to the Hawthorn Group.

Smith (1885) examined samples sent to him by L.C. Johnson and thought the phosphatic limestone at Hawthorne was Eocene or Oligocene, as was the rest of the limestone in the peninsula. However, fossiliferous samples from the Waldo area indicated to Smith that the rocks were Miocene. He considered the rocks near Waldo to be the same as those exposed at Rock Springs in Orange County. Kost (1887), in the first report of the Florida Geological Survey, mentioned the recognition of phosphatic rocks in several locations throughout the state. Penrose (1888) briefly discussed the phosphatic sediments of Alachua County. Johnson (1888) named the Waldo Formation for the phosphatic sediments exposed in eastern Alachua County.

The first major contribution to the understanding of the Miocene phosphatic sediments of Flordia was published by Dall and Harris (1892). Relying upon unpublished data from L.C. Johnson and their own field information, Dall and Harris applied the name "Hawthorne beds" for the phosphatic sediments exposed and quarried near Hawthorne, Alachua County. They reproduced sections and descriptions obtained from Johnson. Dall and Harris placed the "Hawthorne beds" in the "newer" Miocene. Johnson's Waldo Formation was thought to be in the "older" Miocene although Dall and Harris state (p. 111), "Old Miocene phosphatic deposits - These rocks were among those referred by Johnson to his Waldo formation, though typical exposures at Waldo belong to the newer or Chesapeake Miocene." Dall and Harris placed the "Hawthorne beds" in their "Chattahoochee group" which overlies the Vicksburg Group and underlies the "Tampa group" (including their "Tampa limestone" which they felt was younger than the "Hawthorne beds").

The name "Jacksonville limestone" was applied by Dall and Harris (1892) to a "porous, slightly phosphatic, yellowish rock" first recognized by Smith (1885). They thought the "Jacksonville limestone" covered a large area from Duval County to at least Rock Springs in Orange County and included it in the "newer Miocene" above the "Hawthorne beds."

Dall and Harris (1892) examined the sediments in the phosphate mining area on the Peace River and referred to the phosphate-producing horizon as the "Peace Creek bone bed." Underlying the producing zone was a "yellowish sandy marl" containing phosphate grains and mollusk molds which they named the "Arcadia marl." Both units were considered to be Pliocene in age.

Dall and Harris also named the "Alachua clays" stating these clays "occur in sinks, gullies, and other depressions... ." They assigned the Alachua clays to the Pliocene based on vertebrate remains.

Matson and Clapp (1909) considered the Hawthorn to be Oligocene following Dall (1896) who began referring to the "older Miocene" as Oligocene. They considered the Hawthorn to be contemporaneous with the Chattahoochee Formation of west Florida and the Tampa Formation of south Florida. The Hawthorn was referred to as a formation rather than "beds" without formally making the change or designating a type section. Matson and Clapp placed the Hawthorn in their "Apalachicola group." Chert belonging to the "Suwannee limestone" was also included in the Hawthorn Formation at this time.

Matson and Clapp (1909) named the "Bone Valley gravel," replacing the "Peace Creek bone bed" of Dall and Harris (1892). They believed, as did Dall and Harris, that this unit was Pliocene. Matson and Clapp thought that the Bone Valley was predominantly of fluviatile origin and was derived from preexisting formations, especially the "Hawthorn formation." The Bone Valley gravels were believed to be younger than Dall and Harris' "Arcadia marl," older than the Caloosahatchee marl and in part contemporaneous with the "Alachua clays."

Veatch and Stephenson (1911) did not use the term "Hawthorn formation" in describing the sediments in Georgia. Instead the sediments were included in the "Alum Bluff formation" and described as strata lying between the top of the Chattahoochee formation and the base of the Miocene. Overlying their "Alum Bluff" sediments was an argillaceous sand that was in places a friable phosphatic sand which Veatch and Stephenson named the Marks Head marl. The Duplin marl, a coarse phosphatic sand with shells, overlies the Marks Head or the Alum Bluff when the Marks Head is absent.

Sellards (1910, 1913, 1914, 1915) discussed the lithology of the sediments associated with hard rock and pebble phosphate deposits. He presented a review of the origins of the phosphate and their relation to older formations. Sellards (1915) published the section exposed at Brooks Sink in a discussion of the incorporated pebble phosphates.

Matson and Sanford (1913) dropped the "e" from the end of Hawthorne (as Dall and Harris had used it). They state (p. 64), "The name of this formation is printed on the map as Hawthorne, the spelling used in some previously published reports, but as the geographic name from which it is derived is spelled Hawthorn, the final "e" has been dropped in the text." This began a debate of minor importance that continues to the present. Currently the Florida Geological Survey accepts the name without the "e."

Vaughan and Cooke (1914) established that the Hawthorn is not equivalent to or contemporaneous with, any part of the Chattahoochee Formation but is essentially equivalent to the "Alum Bluff formation." They suppressed the name Hawthorn and recommended the use of the name "Alum Bluff formation" and retained the Oligocene age.

Matson (1915) believed that the "Alum Bluff" (Hawthorn) phosphatic limestones formed the bed rock beneath the pebble phosphates of central Florida. This unit had previously been called the "Arcadia marl" (Dall and Harris, 1892). Matson added the sands of the "Big Scrub" in what is now the Ocala National Forest and the sands of the ridge west of Kissimmee (Lake Wales Ridge) to the "Alum Bluff formation." He thought also that the sequence of sediments called the "Jacksonville formation" (formerly the "Jacksonville limestone" of Dall and Harris, 1892) contained units equivalent to the "Alum Bluff formation." Matson thought that the "Bone Valley gravel" and "Alachua clays" were Miocene. He based this on the belief that the elevation of the "Bone Valley gravel" was too high to be Pliocene.

Sellards (1919) considered the "Alum Bluff" to be Miocene rather than Oligocene based on the vertebrate and invertebrate faunas. He stated (p. 294): "In the southern part of the state the deposits which are believed to represent the equivalent of the Alum Bluff formation are distinctly phosphatic." He felt that the deposits referred to the "Jacksonville formation" are lithologically similar to the "Alum Bluff" sediments as developed in south Florida and contain similar phosphatic pebbles. According to Sellards (1919), phosphate first appears in the Miocene "Alum Bluff" rocks, and the "Bone Valley gravels" and the "Alachua clays" represent the accumulation of reworked Miocene sediments.

Mossom (1925, p. 86) first referred the "Alum Bluff" to group status citing "The Alum Bluff is now considered by Miss Gardner as a group... ." Gardner did not publish this until 1926. Gardner (1926), in raising the Alum Bluff to a group, also raised the three members, Shoal River, Oak Grove, and Chipola, to formational status. Mossom (1926) felt the Chipola Formation was the most important and widespread subdivision of the group. He included the fuller's earth beds in north Florida and the phosphatic sands throughout the state in this formation. However, the phosphatic sands were generally referred simply to the Alum Bluff Group. Mossom also believed that the red, sandy clay sediments forming the hills in north Florida belonged in the Chipola Formation.

The Hawthorn Formation was reinstated by Cooke and Mossom (1929), since Gardner (1926) had raised the Alum Bluff to group status. Cooke and Mossom (1929) defined the Hawthorn Formation to include the original Hawthorn "beds" of Dall and Harris (1892) excluding the "*Cassidulus*-bearing limestones" and chert which Matson and Clapp (1909) had placed in the unit. Cooke and Mossom believed the "*Cassidulus*-bearing limestones" and the chert should be placed in the Tampa Limestone (which at that time included strata now assigned to the Suwannee Limestone). They included the "Jacksonville limestone" and the "Manatee River marl" (Dall and Harris, 1892) in the Hawthorn even though they felt the faunas may be slightly younger than typical Hawthorn. They also included Dall and Harris' "Sopchoppy limestone" in the Hawthorn. Cooke and Mossom felt that a white to cream-colored, sandy limestone with brown phosphate grains was the most persistent component of this unit.

Stringfield (1933) provided one of the first, although brief, descriptions of the Hawthorn Formation in central-southern Florida. He noted that the Hawthorn contained more limestone in the lower portion toward the southern part of his study area.

Cooke (1936) extended the Hawthorn Formation as far northeastward as Berkeley County, South Carolina. Cooke (1943, p. 90) states, "The Hawthorn Formation underlies an enormous area that stretches from near Arcadia, Florida, to the vicinity of Charleston, South Carolina." Cooke (1945) discussed the Hawthorn and its occurrence in Florida. The only change suggested by Cooke (1945, p. 192) was to tentatively include the Jacksonville Formation of Dall and Harris (1892) into the Duplin Marl rather than in the Hawthorn as Cooke and Mossom (1929) had done. Cooke (1945) also believed that the Apalachicola

River was the western boundary of the Hawthorn.

Parker and Cooke (1944) investigated the surface and shallow subsurface geology of southernmost Florida. The plates accompanying their report showed the Hawthorn Formation ranging from -10 feet MSL (-3 meters) to -120 feet MSL (-37 meters) overlain by the Tamiami Formation, Caloosahatchee Marl, and Buckingham Marl. Parker (1951) reassigned the upper sequence of Hawthorn sediments to the Tamiami Formation based on his belief that the fauna was Late Miocene rather than Middle Miocene. This significantly altered the concept of Mansfield's (1939) Tamiami Limestone and of the Hawthorn in southern Florida. Parker et al. (1955) continued this concept of the formations.

Cathcart (1950) and Cathcart and Davidson (1952) described the Hawthorn phosphates, their relationship to the enclosing sediments and the lithostratigraphy. Also mentioned is the variation in lithologies and thickness of the Hawthorn within the land pebble district. An excellent description of the Bone Valley Formation was presented by Cathcart (1950).

Vernon (1951) published a very informative discussion of the Miocene sediments and associated problems. Beyond providing data on the limited area of Citrus and Levy Counties, Vernon provided a proposed geologic history of Miocene events. He believed that the Alachua Formation was a terrestrial facies of the Hawthorn and also was, in part, younger than Hawthorn.

Puri (1953) in his study of the Flordia panhandle Miocene referred to the Middle Miocene as the Alum Bluff Stage. He considered the Hawthorn to be one of the four lithofacies of the Alum Bluff Stage.

Yon (1953) investigated the Hawthorn between Chattahoochee in the panhandle and Ellaville on the Suwannee River. Yon included in the Hawthorn the sand and clay unit that was later formally placed in the Miccosukee by Hendry and Yon (1967).

Bishop (1956), in a study of the groundwater and geology of Highlands County, Florida, concluded that the "Citronelle" sands which overlie the Hawthorn graded downward into the Hawthorn. He suggested that these sands be included in the Hawthorn as a non-marine, continental facies deposited as a delta to a large river which existed in Florida during the Miocene.

Pirkle (1956 a, 1956 b, 1957) discussed the sediments of the Hawthorn Formation from Alachua County, Florida. He considered the Hawthorn as a unit of highly variable marine sediments which locally contained important amounts of phosphate. He also regarded the sediments of the Alachua Formation as terrestrial reworked sediments ranging from Lower Miocene to Pleistocene. Later studies by Pirkle, Yoho, and Allen (1965) and Pirkle, Yoho, and Webb (1967) characterized the sediments of the Hawthorn and Bone Valley Formations.

The interest of the United States Geological Survey in the Hawthorn and Bone Valley Formations for their economic deposits of phosphate and related uranium concentrations resulted in a number of publications including Bergendal (1956), Espenshade (1958), Carr and Alverson (1959), Cathcart and McGreevy (1959), Ketner and McGreevy (1959), Cathcart (1963 a, b; 1964; 1966), Espenshade and Spencer (1963), and Altschuler, Cathcart, and Young (1964). With the exception of Espenshade (1958) and Espenshade and Spencer (1963), the studies investigated the strata in the Central Florida Phosphate District and adjacent areas. Espenshade (1958) and Espenshade and Spencer (1963) conducted investigations in north Florida.

Goodell and Yon (1960) provide a discussion of the lithostratigraphy of the post-Eocene rocks from much of the state. They provide a regional lithostratigraphic view of the Miocene sediments in Florida.

The occurrence of magnesian (Mg) rich clays (palygorskite) within the Hawthorn Formation has been investigated by several authors. McClellan (1964) studied the petrology and occurrence of the palygorskite (attapulgite). Gremillion (1965) investigated the origin of the clays. Ogden (1978) suggested depositional environments and the mode of formation of the clays.

Puri and Vernon (1964) summarized the geology of the Hawthorn. They discussed the status of the knowledge of the Hawthorn but added very little new information.

Brooks (1966, 1967) suggested that the Hawthorn should be raised to group status in the future. He further discussed the existence of the Hawthorn across the Ocala Uplift and its subsequent erosional removal. Brooks believed Middle Miocene strata were absent from the Ocala Uplift but were present downdip from the arch. He felt that Lower Miocene beds were present on the arch.

Sever, Cathcart, and Patterson (1967) investigated the phosphate resources and the associated stratigraphy of the Hawthorn Formation in northern Florida and southern Georgia.

Riggs (1967) suggested raising the Hawthorn Formation to group status based on his research in the phosphate district. The rocks of Riggs' "Hawthorn group" were related by containing greater than one percent phosphate grains. The Bone Valley Formation was included as the uppermost unit of the group. Riggs and Freas (1965) and Freas and Riggs (1968) also discussed the stratigraphy of the central Florida phosphate district and its relation to phosphorite genesis.

The geology and geochemistry of the northern peninsular Florida phosphate deposits were investigated by Williams (1971). Clark (1972) investigated the stratigraphy, genesis and economic potential of the phosphorites in the southern extension of the Central Florida Phosphate District.

Weaver and Beck (1977) published a wide ranging discussion of the Coastal Plain Miocene sediments in the southeast. Emphasis was placed on the depositional environments and the resulting sediments, particularly the clays.

Wilson (1977) mapped the Hawthorn and part of the Tampa together. He separated the upper Tampa, termed the Tampa Limestone unit, from the lower "sand and clay" unit of the Tampa Limestone.

Missimer (1978) discussed the Tamiami-Hawthorn contact in southwest Florida and the inherent problems with the current stratigraphic nomenclature. Peck et al. (1979) believed that the definition of the Tamiami by Parker et al. (1955) added to the previously existing stratigraphic problems. Hunter and Wise (1980 a, 1980 b) also addressed this problem suggesting a restriction and redefinition of the Tamiami Formation.

King and Wright (1979) in an effort to alleviate some of the stratigraphic problems associated with the Tampa and Hawthorn formations redefined the Tampa and erected a type section from a core at Ballast Point. Their redefinition restricted the Tampa to the quartz sandy carbonates with greater than 10 percent quartz sand and less than 1 percent phosphate grains. King (1979) presented a discussion of the previous investigations of the Tampa to which the reader is referred. The discussion is not repeated here.

Riggs (1979 a, 1979 b; 1980) described the phosphorites of the Hawthorn and their mode of deposition. Riggs (1979 a) suggested a model for phosphorite sedimentation in the Hawthorn of Florida.

Scott and MacGill (1981) discussed the Hawthorn Formation in the Central Florida Phosphate District and its southern extension. Scott (1983) provided a lithostratigraphic description of the Hawthorn in northeast Florida. Both studies were in cooperation with the United States Bureau of Mines.

T.M. Scott (1981) suggested the Hawthorn Formation had covered much of the Ocala Arch and was subsequently removed by erosion. Scott (1982) designated reference cores for the Hawthorn Formation and compared these to the reference localities previously designated. Scott's (1982) discussion was limited to the northeastern part of the state.

Cyclic sedimentation in the sediments of the Hawthorn was proposed by Missimer and Banks (1982). Their study suggested that reoccurring sediment groups occurred within the formation in Lee County. Also Missimer and Banks followed the suggestions of Hunter and Wise (1980 a, 1980 b) in restricting the definition of the Tamiami. This is also the case in Wedderburn et al. (1982).

Hall (1983) presented a description of the general geology and stratigraphy of the Hawthorn and adjacent sediments in the southern extension of the Central Florida Phosphate District. An excellent discussion of the stratigraphy and vertebrate paleontology of this area was provided by Webb and Crissinger (1983).

Silicification of the Miocene sediments in Florida has been the focus of a number of studies. Strom, Upchurch and Rosenweig (1981), Upchurch, Strom and Nuckles (1982), and McFadden, Upchurch, and Strom (1983) discussed the origin and occurrence of the opaline cherts in Florida. Related to the cherts are palygorskite clays that were also discussed in these papers and by Strom and Upchurch (1983, 1985).

There have been a number of theses completed on various aspects of the Hawthorn Group. These include McClellan (1962), Reynolds (1962), Isphording (1963), Mitchell (1965), Assefa (1969), Huang (1977), Liu (1978), King (1979), Reik (1980), Leroy (1981), Peacock (1981), and McFadden (1982).

Many water resource investigations include a section on the Hawthorn Formation but do not add new geologic or stratigraphic data. These are not included here.

GEOLOGIC STRUCTURE

The geologic structures of peninsular Florida have played an important role in the geologic history of the Hawthorn Group. These features affected the depositional environments and the post-depositional occurrence of the Hawthorn sediments. Due to the nature of the Tertiary sediments in peninsular Florida, it is difficult to ascertain a true structural origin for some of these features. Depositional and erosional processes may have played a role in their development.

The most prominent of the structures in peninsular Florida is the Ocala Platform (often referred to as Ocala Arch or Uplift) (Figure 4). The term platform rather than uplift or arch is preferred here since it does not have a structural connotation.

Originally named the Ocala Uplift by O.B. Hopkins in a 1920 U.S. Geological Survey press release, this feature was formally described by Vernon in 1951. Vernon described it as a gentle flexure developed in Tertiary sediments with a northwest-southeast trending crest. He believed that the crest of the platform has been flattened by faulting. Vernon (1951) dated the formation of the uplift as being Early Miocene based on the involvement of basal Miocene sediments in the faulting and the wedging out of younger Miocene sediments against the flanks of the platform. Cooke (1945) thought that warping began prior to the Late Eocene and continued into the Late Miocene or later. Ketner and McGreevy (1959) suggested that the platform formed prior to Late Miocene since undeformed beds of Late Miocene overlie warped beds of the Ocala Platform. Cooke (1945), Espenshade and Spencer (1963) and T.M. Scott (1981) believed that the Hawthorn once covered most or all of the Ocala Platform. Vernon (1951) believed the Platform was an island area throughout much of the Miocene and the Hawthorn sediments did not extend across the structure. Brooks (1966) believed the feature formed prior to the early Late Miocene. He also agrees with Pirkle (1956 b) that the Hawthorn once extended across the platform.

Riggs (1979 a, b) stated that the Ocala Upland (his term for the Ocala Platform) was a major structural feature controlling the formation and deposition of the phosphorites in the Florida Miocene.

The Sanford High is another important positive feature in the northern half of peninsular Florida (Figure 4). Vernon (1951) proposed the name for a feature located in Seminole and Volusia Counties, Florida. He describes the feature as "a closed fold that has been faulted, the Sanford High being located on the upthrown side." The Hawthorn Group and the Ocala Group are missing from the crest of the Sanford High. The Avon Park Formation lies immediately below post-Hawthorn sediments. The missing section presumably was removed by erosion. Meisburger and Field (1976), using high-resolution seismic reflection profiling, identified a structural high offshore from Daytona Beach in Volusia County and suggested that this feature may be an offshore extension of the Sanford High. Meisburger and Field believed that the seismic evidence indicated uplift that ended prior to Pliocene time. Vernon (1951) believed the feature to be a pre-Miocene structure. Riggs (1979 a, b) considered the Sanford High the "other positive element of extreme importance" in relation to phosphorite deposition.

Extending from the Sanford High are the St. Johns Platform to the north and the Brevard Platform to the south (Figure 4). Both are low, broad ridges or platforms expressed on the erosional surface of the Ocala Group. The St. Johns Platform plunges gently to the north-northwest towards the Jacksonville Basin. The Brevard Platform plunges gently to the south-southeast and southeast. The names of both features were introduced by Riggs (1979 a, b).

The Jacksonville Basin, located in northwest Florida, is the most prominent low in the northern half of the peninsula. In the deepest part of the basin the Hawthorn Group sediments exceed 500 feet (150 meters) in thickness. The name Jacksonville Basin was first used by Goodell and Yon (1960). Leve (1965) believed the basin was at least in part fault controlled.

Previously, many authors included the Jacksonville Basin in the Southeast Georgia Embayment. As more data became available it became apparent that an eastward dipping positive feature, informally named the Nassau Nose (Scott, 1983), separated the Jacksonville Basin from the rest of the Southeast Georgia Embayment. The Jacksonville Basin should still be considered as a subbasin of the larger embayment. The Southeast Georgia Embayment was named by Toulmin (1955) and appears to have been active from Middle Eocene through Miocene time (Herrick and Vorhis, 1963).

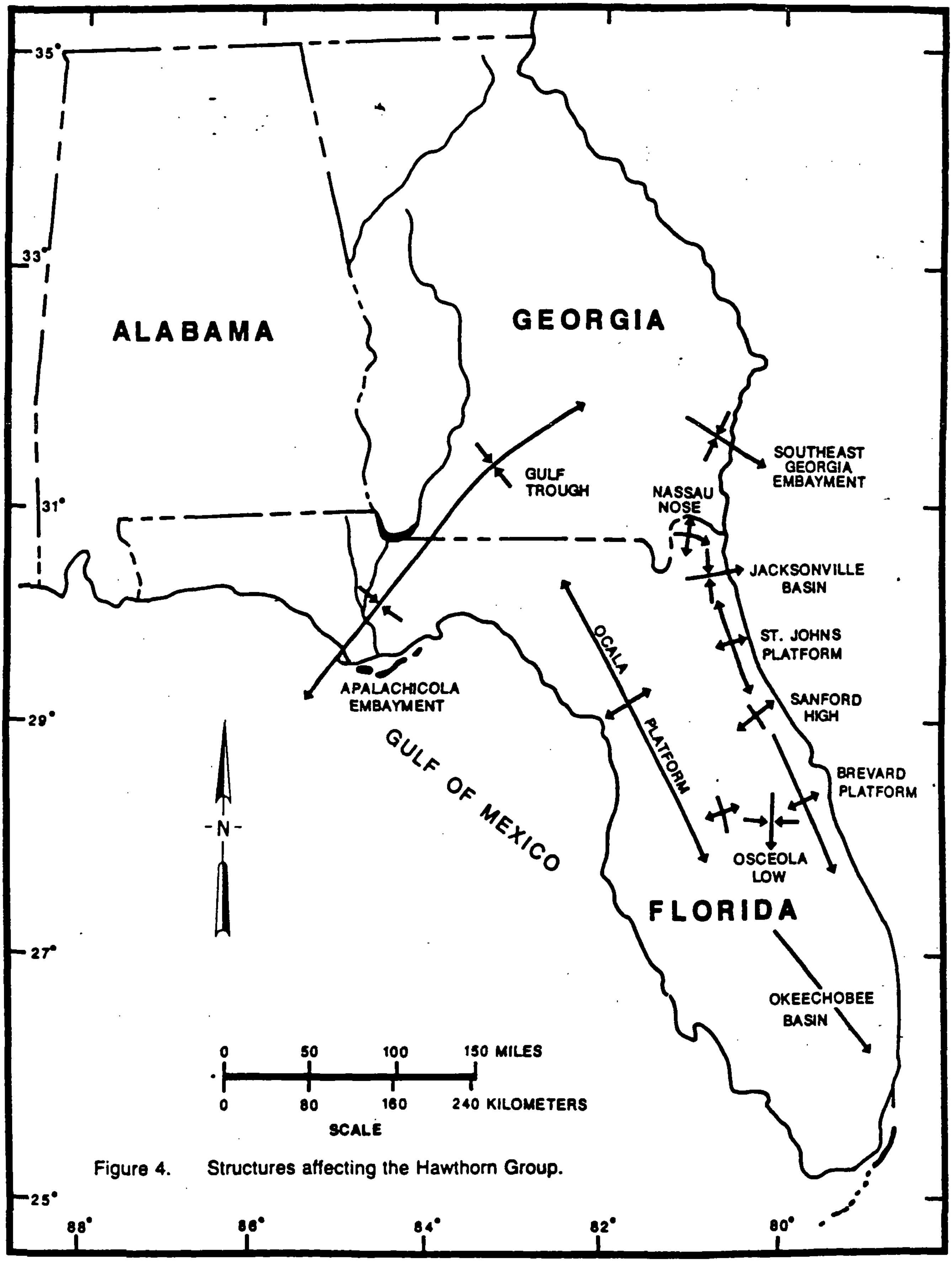


Figure 4. Structures affecting the Hawthorn Group.

The Gulf Trough or Channel extends from the Southeast Georgia Embayment to the Apalachicola Embayment (Figure 4). It is the Miocene expression of the older Suwannee Straits. The Suwannee Straits effectively separated the siliciclastic facies to the north from the carbonate facies to the south during the Early Cretaceous. The Gulf Trough was nearly full of sediments by the Late Oligocene and Early Miocene time, allowing increasing amounts of siliciclastic material to invade the carbonate environments of the peninsular area. Schmidt (1984) provided an excellent discussion of the history of both the Suwannee Strait and the Apalachicola Embayment.

In central peninsular Florida between the southern end of the Ocala Platform and the Brevard Platform are two important features in relation to the Hawthorn Group. The Osceola Low and the Kissimmee Faulted Flexture (Figure 4) were both named by Vernon (1951). Vernon considered the Kissimmee Faulted Flexure to be "a fault-bounded, tilted, and rotated block" with "many small folds, faults, and structural irregularities." His "flexure" is actually a high on the Avon Park surface with the Ocala and Hawthorn Groups absent over part of it due to erosion.

The Osceola Low, as described by Vernon (1951), is a fault-bounded low with as much as 350 feet (106 meters) of Miocene sediments. This author has investigated the Osceola Low using cores, well cuttings and geophysical data (Florida Geological Survey, unpublished data). The data does not indicate the presence of a discrete fault. They do suggest a possible flexure or perhaps a zone of displacement with "up" on the east, "down" on the west. This zone also appears to be the site of increased frequency of karst features developed in the Ocala Group limestone. Scott and Hajishafie (1980) indicated that the Osceola Low trends from north-south to northeast-southwest.

The Okeechobee Basin as named by Riggs (1979 a, 1979 b) encompasses most of southern Florida (Figure 4). It is an area where the strata generally gently dips to the south and southeast. Pressler (1947) referred to this area as the South Florida Embayment stating that its synclinal axis plunged towards the Gulf (to the southwest and/or west). Since this differs significantly from the Okeechobee Basin, the term Okeechobee Basin is preferred and utilized in this study. Within the basin there have been postulated episodes of faulting (Sproul et al., 1972) and folding (Missimer and Gardner, 1976).

INTRODUCTION TO LITHOSTRATIGRAPHY

The Hawthorn Group has long been considered a very complex unit. Puri and Vernon (1964) declared the Hawthorn "the most misunderstood formational unit in the southeastern United States." They further considered it as "a dumping ground for alluvial, terrestrial, marine, deltaic, and pro-deltaic beds of diverse lithologic units... ." Pirkle (1956b) found the dominant sediments to be quite variable stating, "The proportions of these materials vary from bed to bed and, in cases, even within a few feet both horizontally and vertically in individual strata."

HAWTHORN FORMATION TO GROUP STATUS: JUSTIFICATION, RECOGNITION AND SUBDIVISION IN FLORIDA

Formational status has been applied to the Hawthorn since Dall and Harris named the "Hawthorne beds" in 1892. As is evident from the Previous Investigations section, there has been much confusion concerning this unit. The complex nature of the Hawthorn caused many authors to suggest that the Hawthorn Formation should be raised to group status although none formally did so (Pirkle, 1956b; Espenshade and Spencer, 1963; Brooks, 1966, 1967; Riggs, 1967). The Hawthorn was referred to as a group in Georgia for several years on an informal basis until Huddlestun (in press) formalized the status change in the southeastern United States, recognizing its component formations in Georgia. The recognition of formations within the Hawthorn Group in Florida is warranted due to the lithologic complexity of the sediments previously referred to as the Hawthorn Formation. The extension of several Georgia units into Florida and the creation of new Florida units is based on the expectation that Huddlestun will validly publish the status change from formation to group. If he fails to do so, this text will be amended to validate the necessary changes in the proper manner according to the North American Code of Stratigraphic Nomenclature (1983).

An original type locality for the Hawthorn Group was not defined within the limits of our present stratigraphic code. However, it appears that Dall and Harris' (1892) intention was to use the old Simmons pits near Hawthorne in Alachua County as the type locality (holostratotype). The other sections referred to by Dall and Harris (1892) at Devil's Millhopper, Newnansville well, and White Springs were reference sections. The old Simmons pit is no longer accessible indicating the need for a new type locality (neostratotype). The Hawthorne #1 core W-11486, located in Alachua County drilled in the vicinity of the old Simmons pit should fill this gap. As such the Hawthorne #1 core is designated as a neostratotype or replacement (accessible) type section for the Hawthorn Group.

Although many authors have agreed that the Hawthorn deserves group status, questions remain. What should be included in the group and what should be the stratigraphic status of the units (i.e., formations with or without members)? The approach used in this study has been to identify lithostratigraphic units within the study area, determine their areal extent and thickness and, based on these findings, assign a formational status where appropriate. Having done that, as detailed subsequently in this report, the Hawthorn Formation of Florida is herein raised to group status. Its formations are described and type sections or cores are designated in accordance with the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature (NACSN), 1983). Utilizing the group concept will enable geologists to better understand the framework of the Miocene sediments in Florida and much of the southeastern Coastal Plain.

The sediments placed in the Hawthorn Group are related by the occurrence of phosphate, a palygorskite-sepiolite-smectite clay mineral suite and the mixed carbonate-siliciclastic nature of the entire sequence. Color, particularly in the siliciclastic portions, is often distinctive in the sediments of this group. In some regions and in specific intervals, lithologic heterogeneity provides a diagnostic trait of the Hawthorn Group.

The component formations of the Hawthorn Group vary from region to region within the State. The variation is the result of the depositional and environmental controls exerted on the Hawthorn sediments by features such as the Ocala Platform, the Sanford High, the St. Johns Platform, and the Brevard Platform. The variation in component formations of a group is discussed in and accepted by the North American Commission on Stratigraphic Nomenclature (Article 28b, North American Stratigraphic Code, 1983).

The name Hawthorn is retained for the group since the group represents a series of units that had been recognized as the Hawthorn Formation. Only a few changes (additions) are proposed in this report that alter the overall boundaries of the former Hawthorn Formation. Due to its wide use and acceptance, dropping the term Hawthorn and providing a new group name would cause unnecessary confusion.

Once the lithostratigraphic units were determined, names were selected for the respective sections. These are listed in Table 1 along with reference to the original author. When possible, names currently in use, or proposed in a bordering State (Georgia), were used in Florida. Examples of these are the Marks Head, Coosawhatchie and Statenville Formations currently recommended for use in Georgia (Huddlestun, in press). Where a sediment package exhibited significant variation in Florida from the equivalent unit in Georgia, a new name is proposed (i.e., the Penney Farms Formation).

In the eastern panhandle the name Torreya Formation is used since it is already in the literature (Banks and Hunter, 1973; Huddlestun and Hunter, 1982; Hunter and Huddlestun, 1982; Huddlestun, in press) and there is insufficient evidence to suggest any changes. Future research, however, may suggest further changes.

The names of the formational units of the Hawthorn Group in southern Florida were selected based on historical perspective and current usage. The name Arcadia Formation is reintroduced for the Hawthorn carbonate unit. The use of Arcadia is similar to the use suggested by Riggs (1967). Two members are named in the Arcadia, the Tampa Member and the Nocatee Member. These members do not comprise the entire Arcadia but only represent the lower Arcadia where they are identifiable.

The Tampa Member represents a reduction in status for the Tampa from formation to member. Since this reduction represents only a minor alteration of the Tampa definition and since the name Tampa is widely used and recognized, a new name is not suggested for this member. The most prominent reasons for reducing the Tampa to member status is the limited area of recognition and its lithologic affinities with the rest of the Arcadia Formation of the Hawthorn Group.

A new name, the Peace River Formation, is proposed for the upper Hawthorn siliciclastic section, including the Bone Valley Formation of former usage. The Bone Valley Formation is reduced to member status and the name is retained for the same reasons discussed for the Tampa Member. There has been some discussion and disagreement concerning including the entire Bone Valley in the Hawthorn Group due to the presence of a major, Late Miocene unconformity. This unconformity separates the upper gravel bed of the Bone Valley from the remainder of the unit and often is recognizable only on a biostratigraphic basis using vertebrate faunas. The unconformity is generally not recognized on a lithostratigraphic basis. The North American Stratigraphic Code (NACSN, 1983) recognizes this problem. Article 23d states "...a sequence of similar rocks may include an obscure unconformity so that separation into two units may be desirable but impractical. If no lithic distinction adequate to define a widely recognizable boundary can be made, only one unit should be recognized, even though it may include rock that accumulated in different epochs, periods or eras (NACSN, 1983)."

The formations of the Hawthorn Group are similar yet different in northern and southern Florida and in the eastern panhandle. Also, within southern Florida, the group varies from east to west. As a result the discussion of the Hawthorn will be presented separately for northern and southern Florida and the eastern Florida panhandle (Figure 1).

PRESENT OCCURRENCE

The Hawthorn Group underlies much of peninsular Florida (Figures 5 and 6). It is absent from most of the Ocala Platform and Sanford High due to erosion. Outliers of Hawthorn sediments and residuum occur scattered along the platform in lows and in some karst features. The Hawthorn Group sediments are also absent from part of Vernon's (1951) Kissimmee Faulted Flexure in Osceola County presumably due to erosion.

The Hawthorn Group dips gently away from the Ocala Platform and Sanford High at generally less than 6 feet per mile (1.1 meters per kilometer) (Figure 5). In north Florida, the Hawthorn dips generally to the east and northeast towards the Jacksonville Basin and the east coast. Locally the dip may become greater and may reverse in some areas. This is due to postdepositional movement related to karst activity, subsidence, possible faulting, and tilting of the platform. Scott (1983) indicated this on structure maps of the Ocala Group (p. 29) and the Hawthorn Formation (p. 32).

In central and south Florida the Hawthorn Group dips gently to the south and southeast with local variations (Figure 5). Generally, further south in the state the dip is more southeasterly. The strata dip to the west and southwest along the western edge of the state from Pasco County south to Lee County.

The Hawthorn Group ranges in thickness from a feather edge along the positive features to greater than 500 feet (160 meters) in the Jacksonville Basin and greater than 700 feet (210 meters) in the Okeechobee Basin (Figures 4 and 6). The Hawthorn generally thickens to the northeast in north Florida toward the Jacksonville Basin and southward into the Okeechobee Basin (Figure 6).

NORTH FLORIDA

INTRODUCTION

The Hawthorn Group in Florida, north of Orange County and west through Hamilton County, has distinct affinities to the Hawthorn in Georgia. The sediments of the upper two-thirds of the group are very similar to those in Georgia, facilitating the use of the same terminology in both states. The basal one-third of the group changes significantly into Florida and, therefore, a new formational name is proposed.

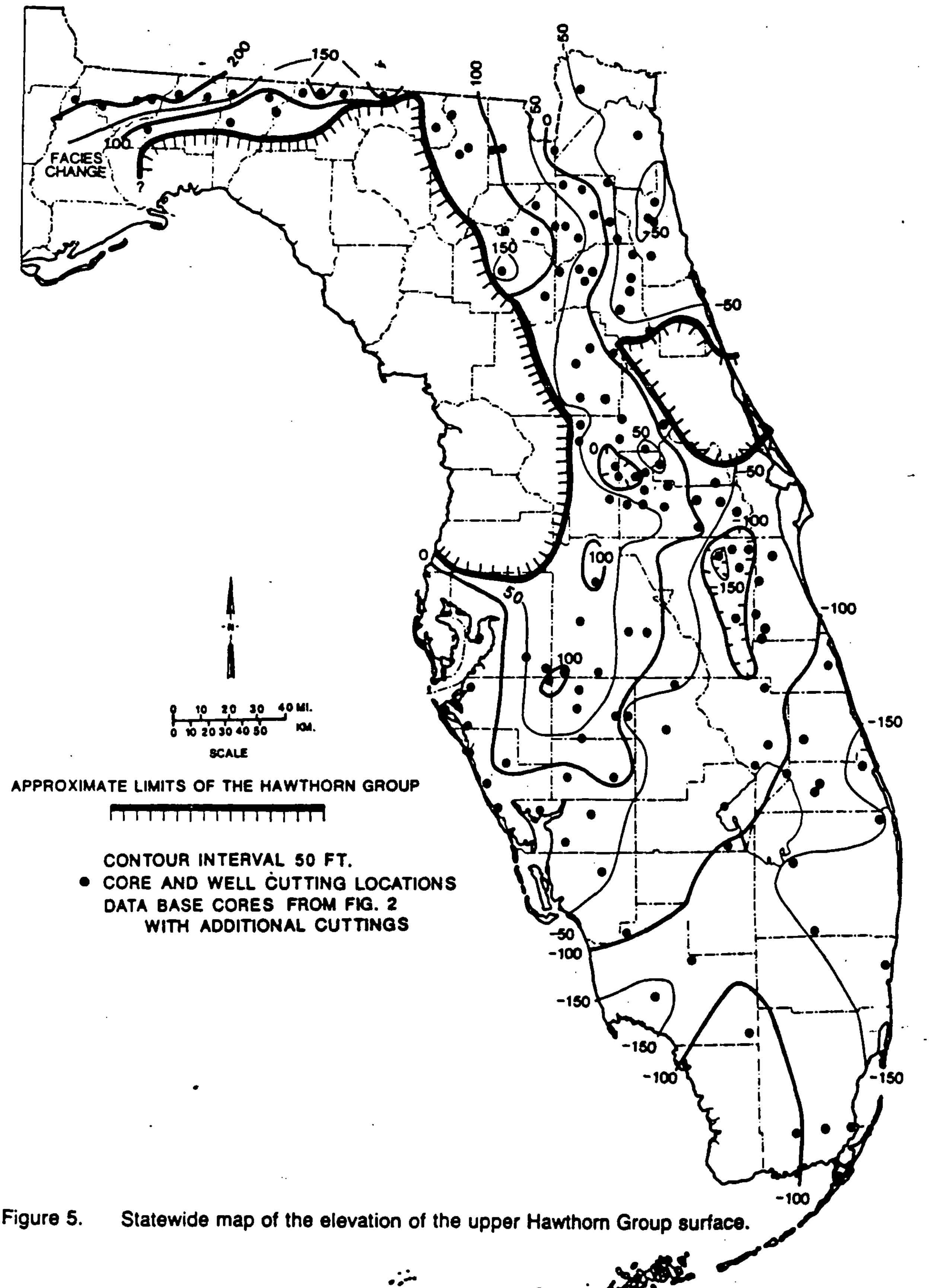


Figure 5. Statewide map of the elevation of the upper Hawthorn Group surface.

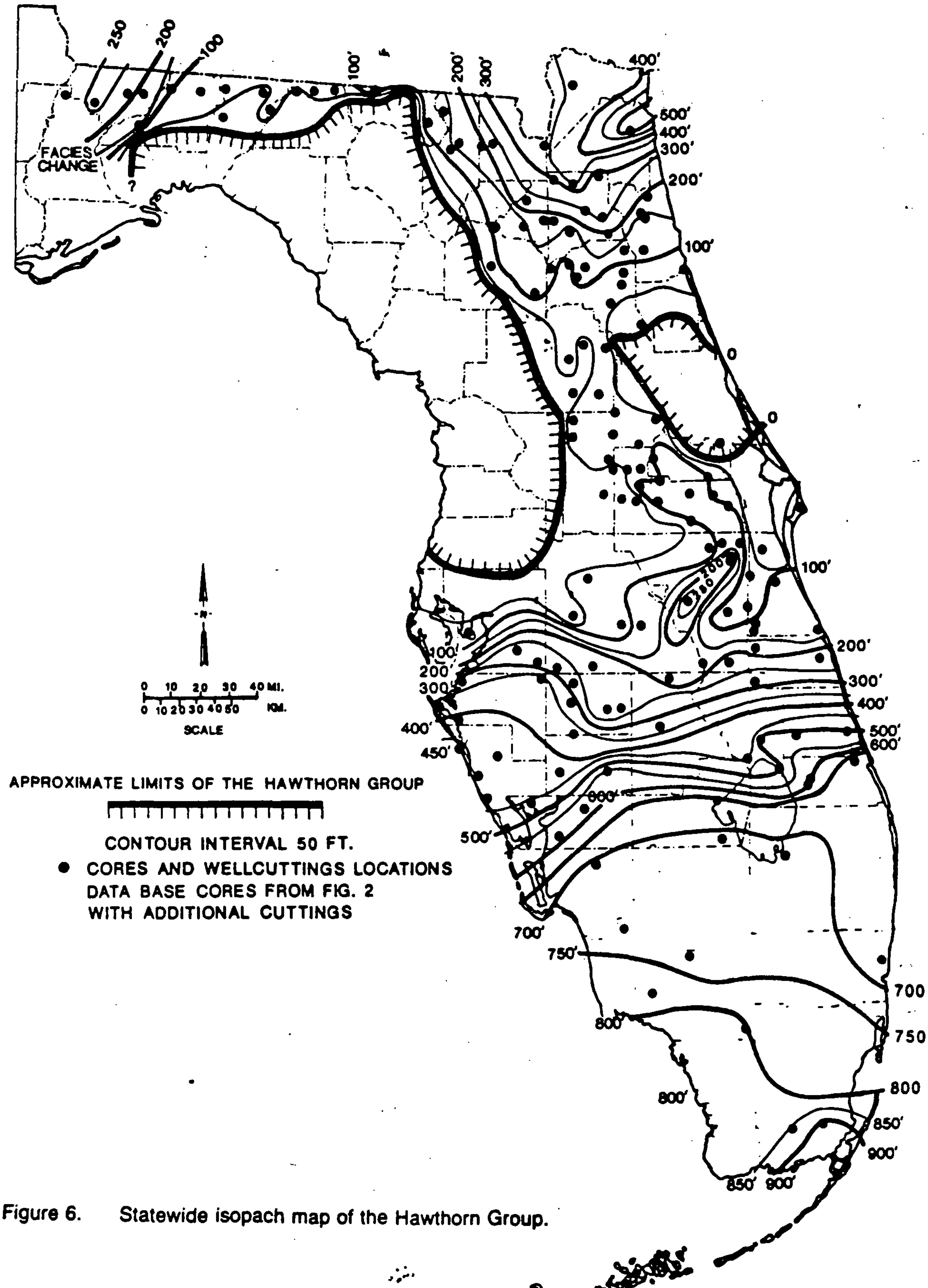
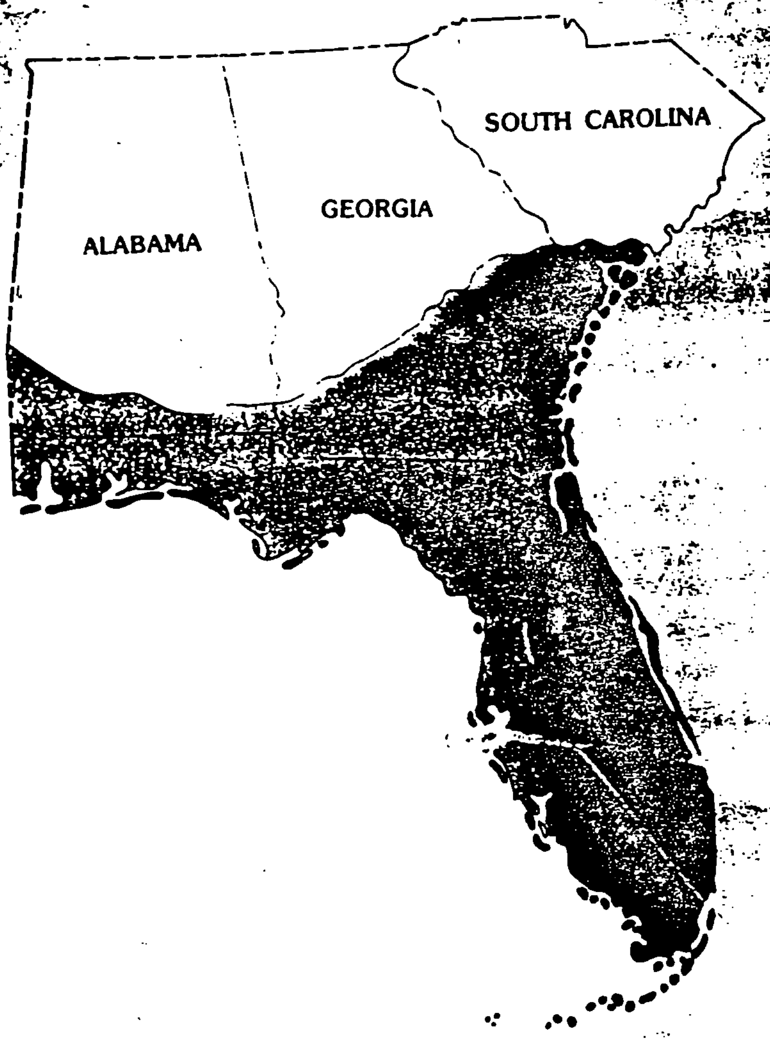


Figure 6. Statewide isopach map of the Hawthorn Group.

HYDROGEOLOGIC FRAMEWORK OF THE FLORIDAN AQUIFER SYSTEM IN FLORIDA AND IN PARTS OF GEORGIA, ALABAMA, AND SOUTH CAROLINA

REFERENCE 13



U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1403-B

UPPER CONFINING UNIT

Over much of the study area, the Floridan aquifer system is overlain by an upper confining unit that consists mostly of clastic rocks but locally contains much low-permeability limestone and dolomite in its lower parts. In places, the upper confining unit has been removed by erosion, and the Floridan either crops out or is covered by only a thin veneer of permeable sand that is part of the surficial aquifer. Because the lithology and thickness of the upper confining unit are highly variable, the unit retards the vertical movement of water between the surficial aquifer and the Floridan aquifer system in varying degrees. Where the upper confining unit is thick or where it contains much clay, leakance through the unit is much less than where it is thin or highly sandy. In these thick or clay-rich areas, therefore, water in the surficial aquifer moves mostly laterally and is discharged into surface-water bodies rather than moving downward through the upper confining unit (when the head differential is favorable) to recharge the Floridan aquifer system.

The upper confining unit may be breached locally by sinkholes and other openings that serve to connect the Floridan aquifer system directly with the surface. These sinkholes are for the most part found where the thickness of the upper confining unit is 100 ft or less. They appear to result from the collapse of a relatively thin cover of clastic materials into solution features developed in the underlying limestone of the Floridan aquifer system rather than from the solution of limestone beds within the upper confining unit itself. The upper confining unit is generally more sandy where it is less than 100 ft thick because these relatively thin areas represent upbasin depositional sites where coarser clastic rocks were laid down. Plate 25 shows the extent and thickness of the upper confining unit. The maximum measured thickness of the unit is about 1,890 ft in well ALA-BAL-30 in Baldwin County, Ala. The maximum contoured thickness is 1,900 ft. Plate 25 also shows areas where water in the Floridan aquifer system occurs under unconfined, thinly confined (thickness of upper confining unit between 0 and 100 ft), and confined conditions.

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FLORIDAN AQUIFER SYSTEM

GENERAL

The Floridan aquifer system is a thick sequence of carbonate rocks generally referred to in the literature as the "Floridan aquifer" in Florida and the "principal artesian aquifer" in Georgia, Alabama, and South Carolina. As defined in this report, the Floridan aquifer system encompasses more of the geologic section and extends over a wider geographic area than either the Floridan or the principal artesian aquifer, as those aquifers have been described in the literature. Figure 7 shows the geologic formations in Florida and southeastern Georgia that were called "principal artesian formations" by Stringfield (1936), those that were included in the "Floridan aquifer" as defined by Parker and others (1955), and those placed in the "principal artesian aquifer" as defined by Stringfield (1966). Subsequent deep drilling and hydraulic testing have shown that highly permeable carbonate rocks extend to deeper stratigraphic horizons than those included in either the "Floridan" or "principal artesian" aquifers as originally described. Accordingly, this author (cited by Franks, 1982) extended the base of the Floridan aquifer downward to include part of the upper Cedar Keys Limestone (fig. 7). Limestone and dolomite beds that commonly occur at the base of the Hawthorn Formation have been included as part of the "Floridan" or "principal artesian" aquifer in most previous reports. However, data collected for the present study show that, except very locally, there are no high-permeability carbonate rocks in the lower part of the Hawthorn Formation that are in direct hydraulic contact with the main body of the Floridan aquifer system.

The Hawthorn Formation was thus excluded from the aquifer system in a report by Miller (1982a) that was one of a series of several interim reports published during the present study. In these interim reports, the aquifer system was called the "Tertiary limestone aquifer system of the Southeastern United States." This cumbersome, albeit more accurate, terminology has subsequently been abandoned, and the aquifer system is referred to in this professional paper as the "Floridan aquifer system" (see Johnston and Bush, 1985 for a more detailed history of the terminology applied to the aquifer system).

The Floridan aquifer system is defined in this report

EPOCH		Stringfield (1936) Formation	Stringfield (1936) Aquifer	Parker and others (1955) Formation	Parker and others (1955) Aquifer	Stringfield (1966) Formation	Stringfield (1966) Aquifer	Miller, in Franks (1982) Formation	Miller, in Franks (1982) Aquifer	Miller (1982 a,c) Formation	Miller (1982 a,c) Aquifer system	This Report Formation	This Report Aquifer system
MIOCENE	Middle	Hawthorn Formation		Hawthorn Formation	Where Permeable	Hawthorn Formation		Hawthorn Formation		Hawthorn Formation		Hawthorn Formation	
MIOCENE	Early	Tampa Limestone	Principal artesian formations	Tampa Limestone	Floridan aquifer	Tampa Limestone	Principal artesian aquifer	Tampa Limestone	Where Permeable	Tampa Limestone	Where Permeable	Tampa Limestone	Where Permeable
OLIGOCENE		Oligocene Limestone		Suwannee Limestone		Suwannee Limestone		Suwannee Limestone	Floridan aquifer	Suwannee Limestone	Tertiary limestone aquifer system	Suwannee Limestone	Floridan aquifer system
EOCENE	Late	Ocala Limestone		Ocala Limestone		Ocala Limestone		Ocala Limestone		Ocala Limestone		Ocala Limestone	
EOCENE	Middle			Avon Park Limestone / Lake City Limestone		Avon Park Limestone / Lake City Limestone		Avon Park-Lake City Limestones		Avon Park-Lake City Limestones		Avon Park Formation	
EOCENE	Early					Oldsmar Limestone		Oldsmar Limestone		Oldsmar Limestone		Oldsmar Formation	
PALEOCENE								Cedar Keys Limestone		Cedar Keys Limestone		Cedar Keys Formation	

Figure 7. Comparison of aquifer terminologies.

as a vertically continuous sequence of carbonate rocks of generally high permeability that are mostly of middle and late Tertiary age and hydraulically connected in varying degrees and whose permeability is, in general, an order to several orders of magnitude greater than that of those rocks that bound the system above and below. As plate 2 shows, the Floridan aquifer system includes units of late Paleocene to early Miocene age. Very locally, in the Brunswick, Ga., area, the entire Paleocene section plus a thick sequence of rocks of Late Cretaceous age are part of the aquifer system. In and just downdip of the area where the aquifer system crops out, the entire system consists of one vertically continuous permeable unit. Farther downdip, less permeable carbonate units of subregional extent separate the system into two aquifers, herein called the Upper and Lower Floridan aquifers (fig. 8). These less permeable units may be very leaky to virtually nonleaky, depending on the lithologic character of the rock comprising the unit. Because they lie at considerable depth, the hydrologic character and the importance of the subregional low-permeability units are known from only a few scattered deep test wells. Local low-permeability zones may occur within either the Upper or the Lower Floridan aquifer. In places (for example, southeastern Florida), low-permeability rocks account for slightly more than half of the rocks included in the aquifer system.

Even though the rocks that comprise the base of the Upper Floridan aquifer are not everywhere at the same altitude or geologic horizon or of the same rock type, the presence of a middle confining unit over about two-thirds of the study area has led to a conceptual model for the Floridan aquifer system that consists of two active permeable zones (the Upper and Lower Floridan aquifers) separated by a zone of low permeability (a middle confining unit). Because of this simplified layering scheme, it is necessary to greatly generalize the highly complex sequence of high- and low-permeability rocks that comprise the aquifer system. Local confining beds (see, for example, cross section E-E', pl. 21) are either disregarded because they are regionally unimportant or lumped with one of the major layers. The purpose of the conceptual model, and of the digital computer model derived from it and described by Bush and Johnston (1985) is to portray the major aspects of ground-water flow within the Floridan aquifer system. In like manner, the descrip-

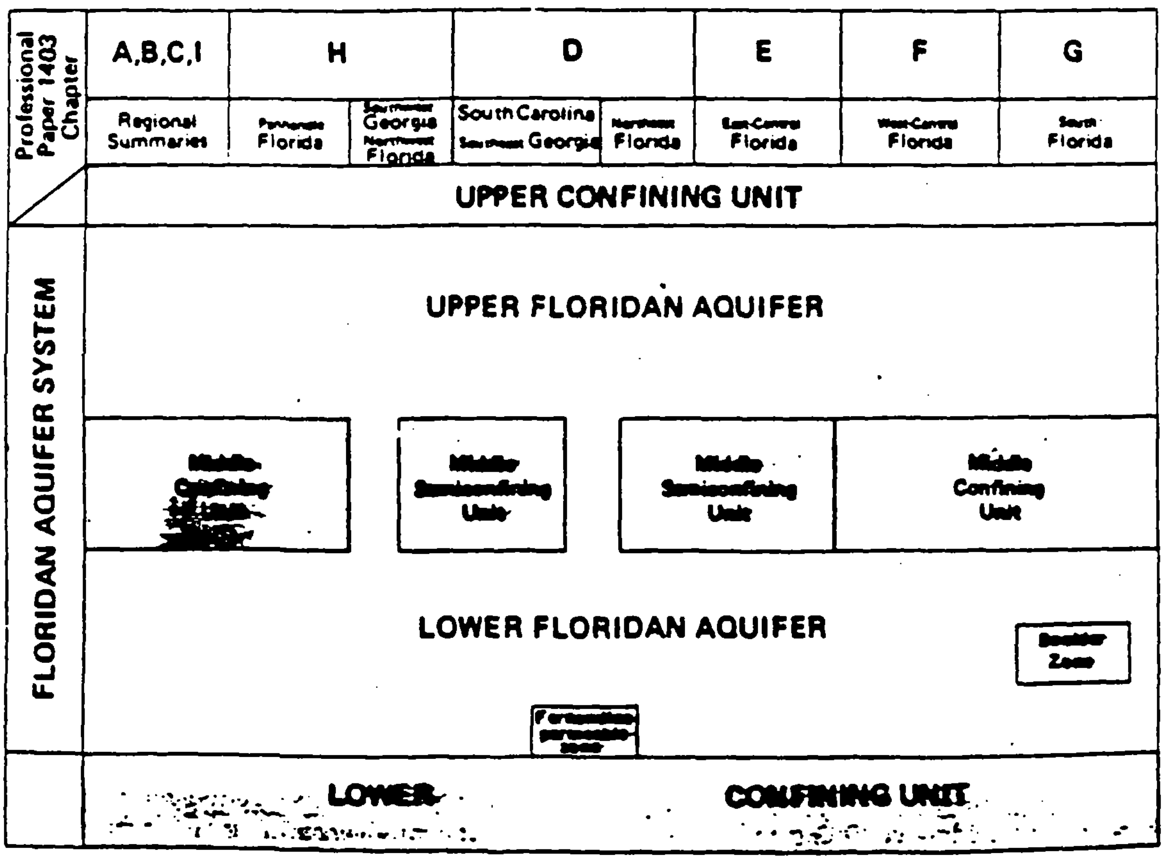


Figure 8. Aquifers and confining units of the Floridan aquifer system.

tion of the aquifer system's geohydrologic framework in this report is intended to show the principal variations in permeability within the aquifer system. In both cases, local anomalies that do not fit with overall (regional) conditions are ignored.

Regionally, the top of the Floridan aquifer system in most places lies at the top of rocks of Oligocene age (Suwannee Limestone) where these strata are preserved. Where Oligocene rocks are absent, the aquifer system's top is generally at the top of upper Eocene rocks (Ocala Limestone). Locally, in eastern panhandle Florida and in west-central peninsular Florida, rocks of early Miocene age (Tampa Limestone) are highly permeable and hydraulically connected to the aquifer system. In places, upper Eocene through lower Miocene rocks are either missing owing to erosion or nondeposition or of low permeability; at these places, rocks of middle Eocene age (Avon Park Formation) mark the top of the aquifer system. It is important to note that there are some places where the upper part of a given formation that comprises the top of the aquifer system consists of low-permeability rocks. At such places, the low-permeability beds are excluded from the aquifer system, and the top of the system is considered to be the top of the uppermost high-permeability carbonate rock. The top of the system, then, may lie within a stratigraphic unit rather than at its top. Because the permeability contrast between the aquifer system and its upper confining unit does not everywhere follow stratigraphic horizons, neither does the top of the aquifer system. Likewise, the top of the aquifer system may locally lie within a limestone unit if the upper part of the limestone consists of low-permeability rock and the lower part is highly permeable.

The time-stratigraphic units or parts of units that mark the top of the Floridan aquifer system at selected localities are shown in figure 9, as well as the time-rock units that comprise the Upper and Lower Floridan aquifers and the units that are considered to represent the aquifer system's base. Figure 9 shows a series of idealized chronostratigraphic columns compiled from well data at several locations in the study area, along with the permeability characteristics of each chronostratigraphic unit at each location. Examination of this figure shows that, in addition to the variations in the top and base of the aquifer system, the degree of permeability varies greatly within the system. Generally (and as figure 9 shows), the aquifer system in many places can be divided into an Upper and Lower Floridan aquifer separated by less-permeable rock. In some places, however, no middle confining unit exists (for example, the Baxley, Ga., and Gainesville, Fla., columns in fig. 9), and the aquifer system is highly permeable throughout its vertical extent. In other places, thick sequences of low-permeability rock occur at several levels within the aquifer system (for example, the Savannah, Ga., and West Palm Beach, Fla., areas in fig. 9), and the several discrete permeable zones of the system may be hydraulically separated.

Regionally, and in a fashion similar to the way in which the top is defined, the base of the aquifer system is defined as the level below which there is no high-permeability carbonate rock. The base of the system is generally either (1) glauconitic, calcareous, argillaceous to arenaceous rock that ranges in age from late Eocene to late Paleocene (fig. 9) or (2) massively bedded anhydrite that commonly occurs in the lower two-thirds of the Paleocene Cedar Keys Formation. Locally, near Brunswick, Ga., micritic limestone and argillaceous limestone of Late Cretaceous (Tayloran) age mark the base of the aquifer system. The permeability of the micritic and argillaceous carbonate rocks, the anhydrite beds, and the various clastic rocks that comprise the base of the system is much less than that of the carbonate rocks above. Regardless of its lithologic character, the lower confining unit, whose top is mapped in this report as the base of the aquifer system, everywhere separates the system from deeper, predominantly clastic aquifers of early Tertiary and Late Cretaceous age.

The upper confining unit of the Floridan aquifer system generally consists of rocks of middle and late Miocene age. Where older rocks such as the lower Miocene Tampa or Oligocene Suwannee Limestones are of low permeability, they are also included in the upper confining unit. In parts of the study area, the upper confining unit has been removed by erosion and the aquifer system either: crops out, is covered by only a surficial sand aquifer, or is covered very locally by clayey residuum. Hydraulic conditions within the aquifer system accordingly vary from confined to unconfined. Where thick sequences of less permeable rocks of subregional extent are present within the aquifer system, they divide it into two major aquifers. The uppermost aquifer (Upper Floridan) generally consists of rocks of Oligocene, late Eocene, and late middle Eocene age (fig. 9). The lower aquifer (Lower Floridan) generally consists of rocks of early middle Eocene to late Paleocene age. Where no middle confining unit separates the two aquifers, all the permeable rock comprising the aquifer system is referred to as the Upper Floridan aquifer. The middle confining unit separating the Upper and Lower Floridan aquifers is generally found in the middle part of rocks of middle Eocene age. The less permeable material that comprises the middle confining unit, however, is not everywhere of the same age (fig. 9), nor does it everywhere consist of the same rock type, as a later section of this report discusses in detail.

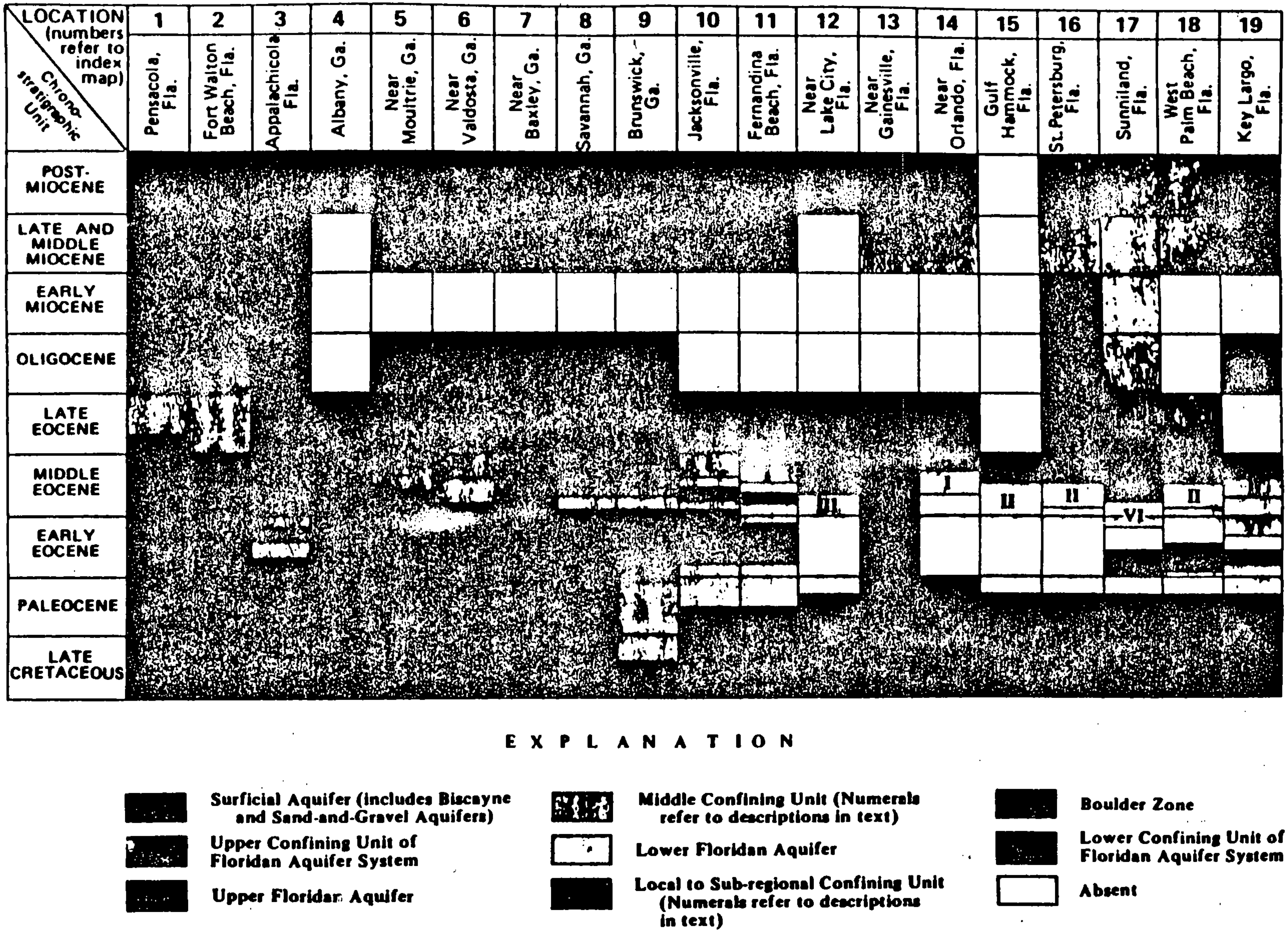


Figure 9. Relation of time-stratigraphic units to the Floridan aquifer system, its component aquifers, and its confining units.

Throughout much of the study area, the water in the Lower Floridan is brackish to saline. The Lower Floridan is moderately to highly porous, and digital simulation indicates that it transmits water sluggishly (see Bush and Johnston, 1985). Little is known about the Lower Floridan aquifer because in most places there is no reason to drill into a deep aquifer containing poor-quality water when an adequate shallower source of good-quality water (the Upper Floridan aquifer) exists.

Local to subregional zones of cavernous permeability occur at several levels within the Floridan aquifer system. The best known of these zones, called the "Boulder Zone" (Kohout, 1965) because of its difficult drilling characteristics, is found in the lower part of rocks of early Eocene age (fig. 9) in southern Florida. Borehole televiewer surveys show that this zone consists of a series of thin to moderately thick horizontal openings connected vertically by fractures, some of which have been opened and enlarged into vertical tubes by solution. The Boulder Zone resembles modern cave systems and is presumed to have formed in a similar fashion—by solution at or above an early Eocene paleowater table. As a result, the transmissivity of the Boulder Zone is extremely high (Meyer, 1974). Other shallower, less extensive cavernous zones are found farther north in the Florida peninsula (Miller, 1979). Where these cavernous zones are developed in the parts of the aquifer system that contain saline water, they are used as receiving zones for underground injection of treated sewage and other industrial wastes.

Within the sequence of rocks that is here treated as an upper confining unit are permeable zones that extend over part of a county or over several counties and that are important local sources of water. These localized artesian aquifers are considered in this report to comprise part of the upper confining unit of the Floridan aquifer system because their permeability is low in comparison with that of the Floridan and because they are of limited extent.

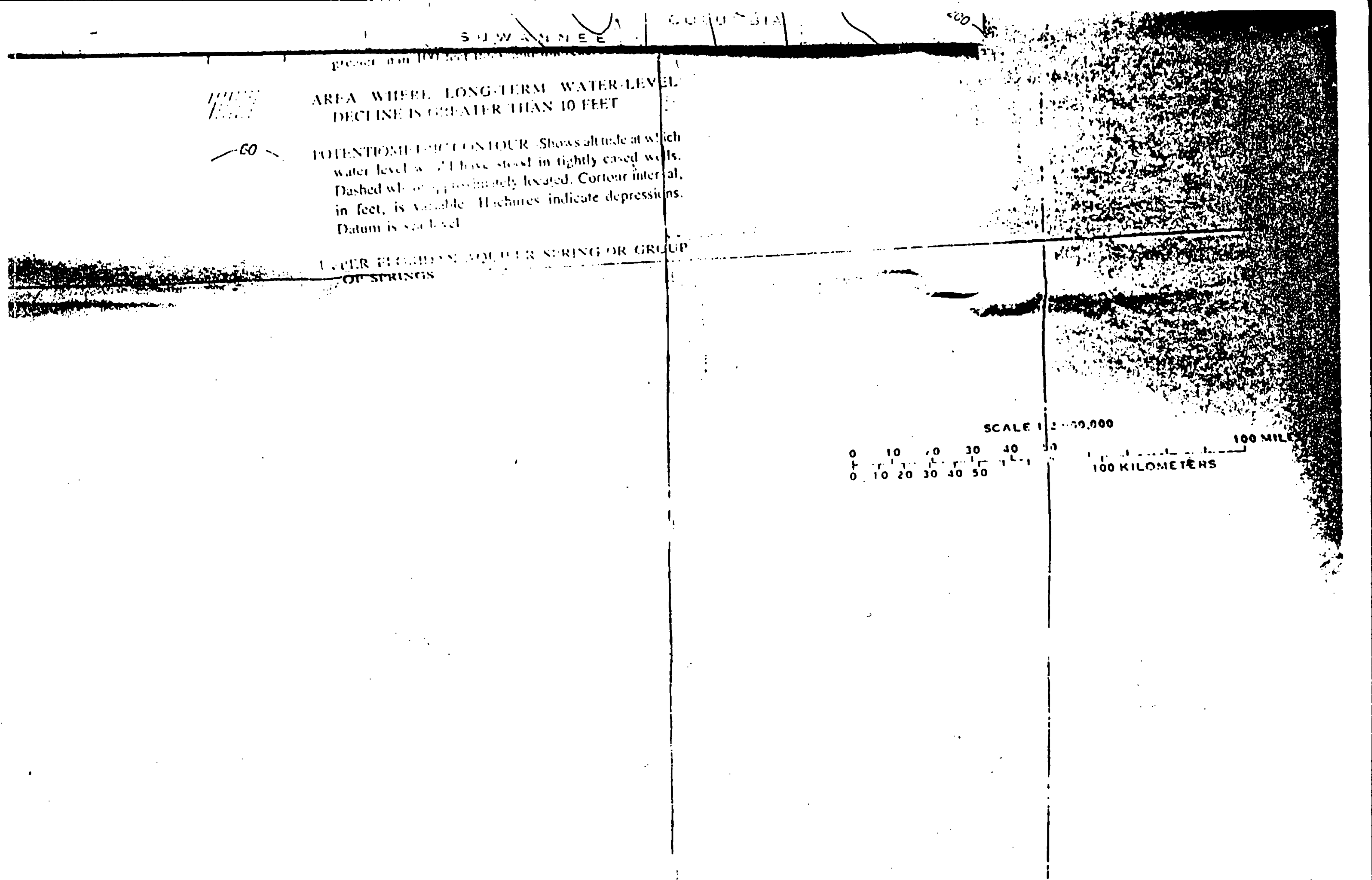
EXTENT

The Floridan aquifer system becomes thin in updip areas where it is interbedded with clastic rocks. The limestones that comprise the aquifer system grade in an updip direction into sandy or argillaceous limestone, which in turn grades into calcareous sand or clay. Still farther updip, these calcareous clastic rocks grade into fully clastic sediments that are stratigraphically equivalent to the aquifer system but are much less permeable than their limestone equivalents. The updip facies change from limestone into clastic rocks and the corresponding decrease in the amount of highly permeable rock in an updip direction are shown by geohydrologic cross-sections A-A', B-B', C-C', D-D' and O'-O" (pl. 15, 16, 18, 19, 20). The updip limit of the Floridan aquifer system (plate 26) has been arbitrarily placed where the thickness of the system is less than 100 ft and where the clastic rocks interbedded with the limestone make up more than 50 percent of the rock column between the uppermost and lowermost limestone beds that can be shown to be connected downdip. To the north and west of the line shown as the approximate updip limit of the aquifer system, thin beds, lenses, and stringers of limestone may be either connected to the main limestone body or isolated from it because of postdepositional erosion. Although these thin beds and outliers locally yield water in small to moderate amounts, they are not considered in this report to be part of the Floridan aquifer system.

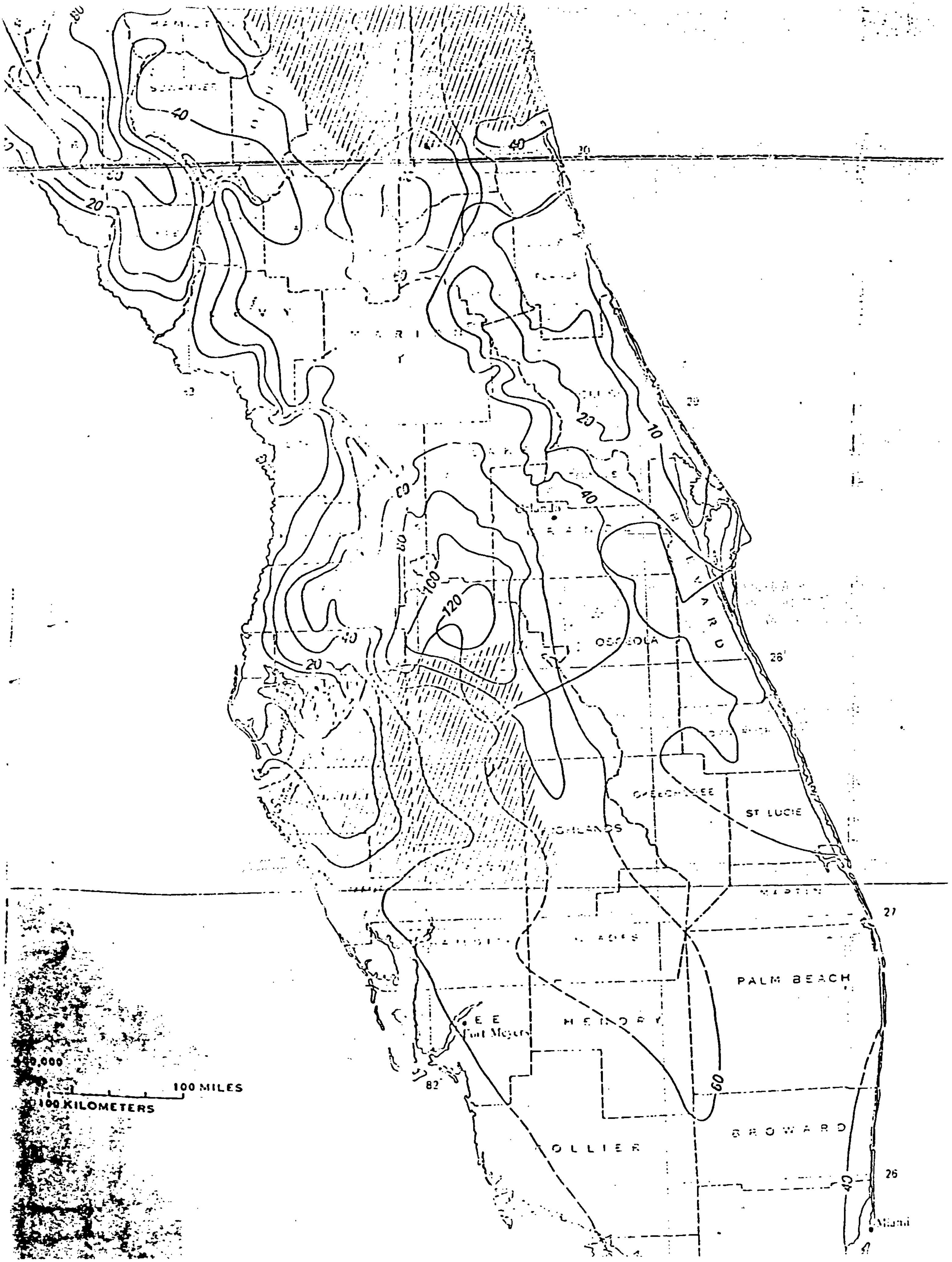
The Floridan aquifer system is known to extend offshore from Georgia (McCollum and Herrick, 1964) and peninsular Florida (Rosenau and others, 1977; Schlee, 1977; Johnston and others, 1982). Because offshore geologic and hydrologic data are sparse, however, the aquifer system is not mapped offshore in this report. The Floridan contains fresh to brackish water in some offshore areas (Johnston and others, 1982), but sparse data on water quality mandate mapping of the aquifer system's freshwater-saltwater interface by indirect methods (Bush and Johnston, 1985; Sprinkle, 1985).

In part of the mapped area in South Carolina, the Upper Floridan aquifer has passed by facies change into low-permeability clastic rocks, and only the Lower Floridan aquifer is present. The effect is that of a pinchout of the Upper Floridan. The approximate area of facies change within the Upper Floridan is shown on plate 26 by a dashed northwest-trending line whose location is based on widely scattered well control. Contours to the northeast of the line represent the top of a middle confining unit that is underlain by the Lower Floridan aquifer at an altitude several hundred feet lower. Other water-bearing limestone units in South Carolina are located northeast of the area mapped in this report, but they are either hydraulically separate from the Floridan aquifer system or their permeability is too low to warrant including them in the system.

A series of faults in southwestern Alabama shown on plate 26 marks the updip limit of the aquifer system. These arcuate faults, which are part of the Gilbertown-Pickens-Pollard fault zone, bound a series of grabens. Movement along these faults has juxtaposed low-permeability clastic rocks within the grabens opposite the permeable limestone that comprises the aquifer system. The north-trending, sinuous, fault-bounded feature in Washington and Mobile Counties,

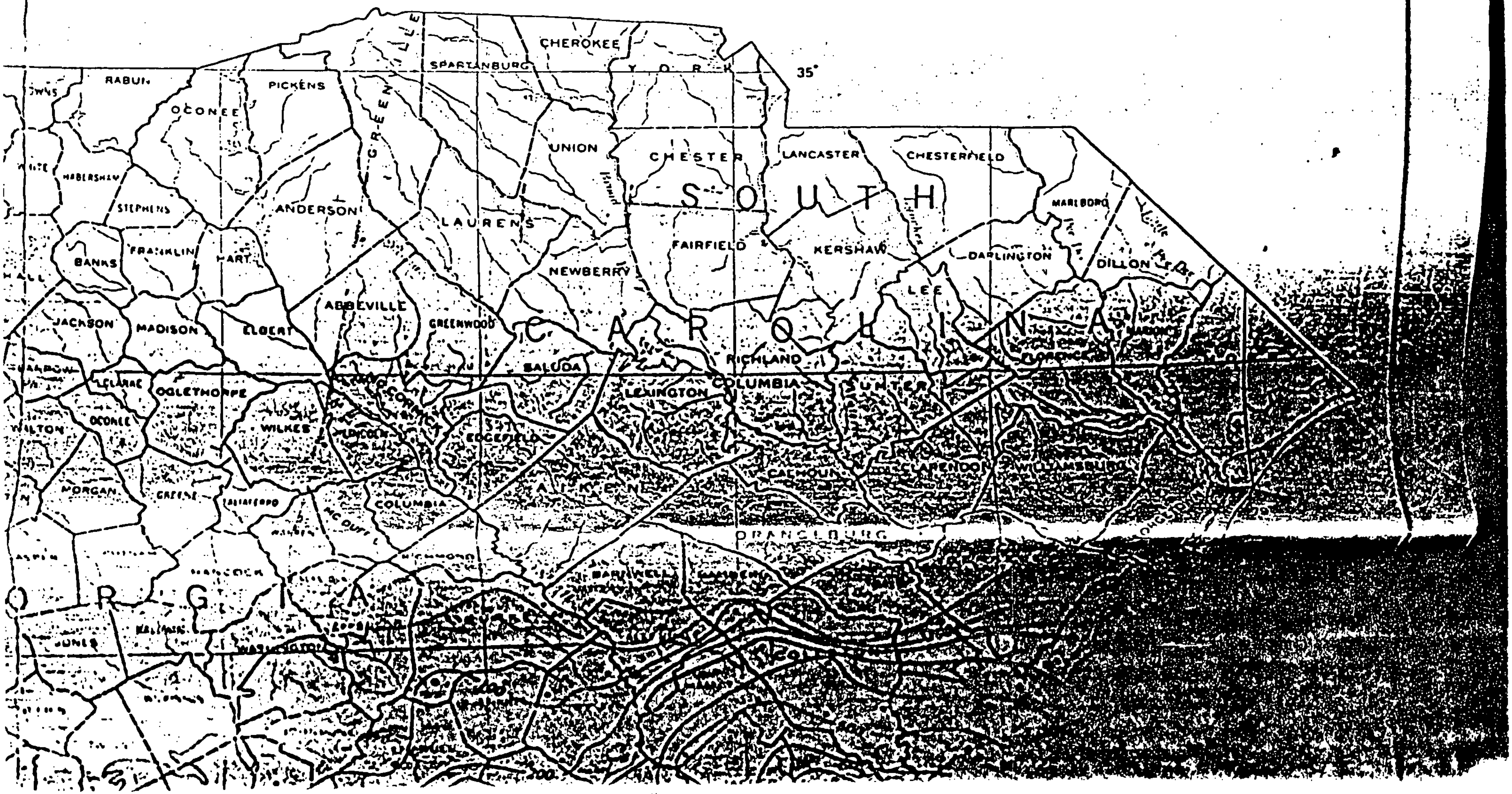


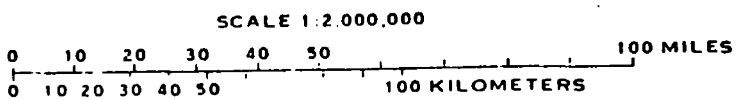
OCCURRENCE OF UNCONFINED, SEMICONFINED AND CONFINED CON
AND POTENTIOMETRIC SURFACE (1980) OF THE UPPER FLORIDAN A



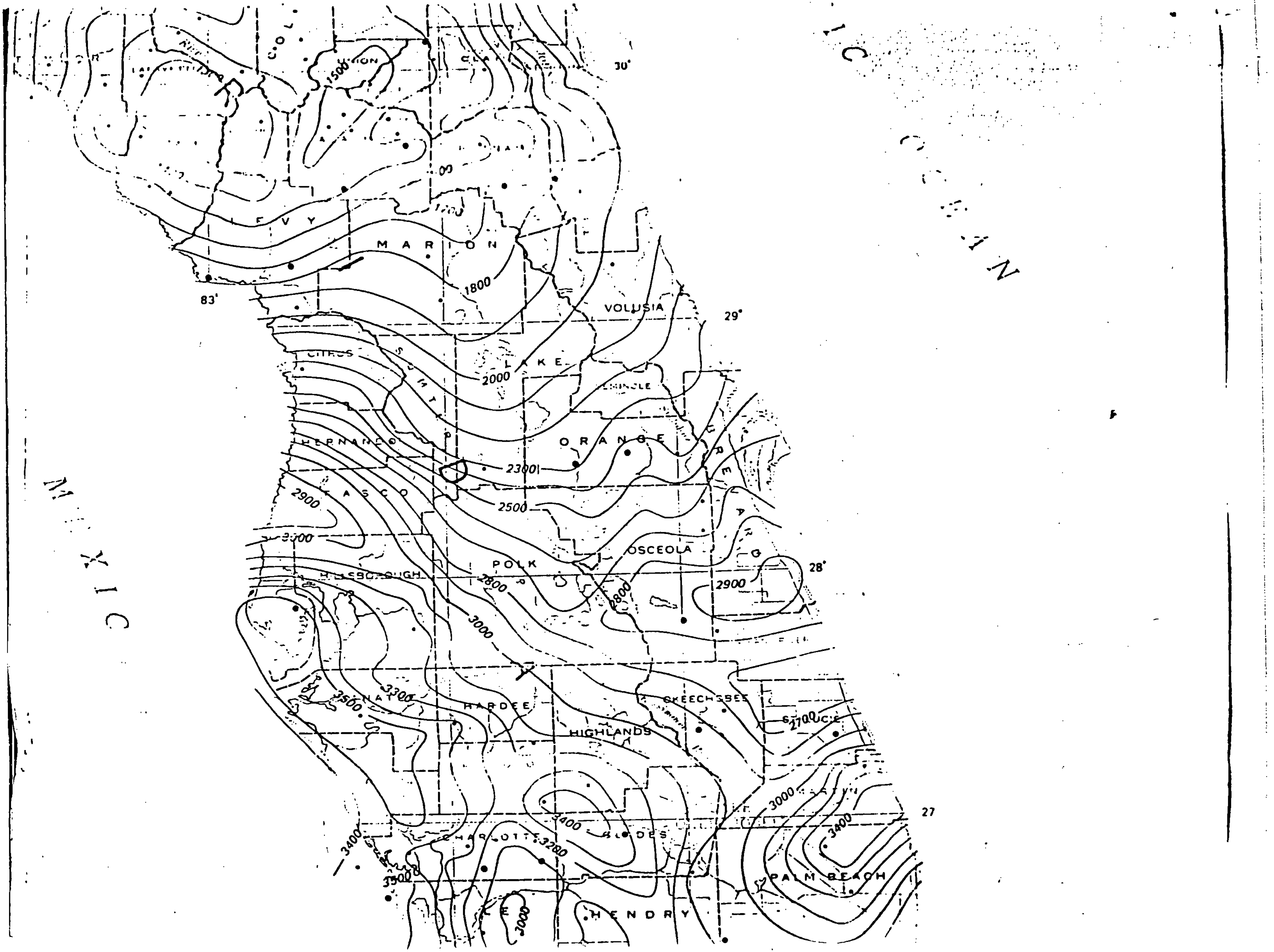
PALM BEACH
BROWARD
ST LUCIE
OSCEOLA
Fort Meyers
Miami
100 MILES
100 KILOMETERS
82°
30
29
28
27
26
120
100
80
60
40
20
10

PROFESSIONAL PAPER 1403-B
PLATE 27





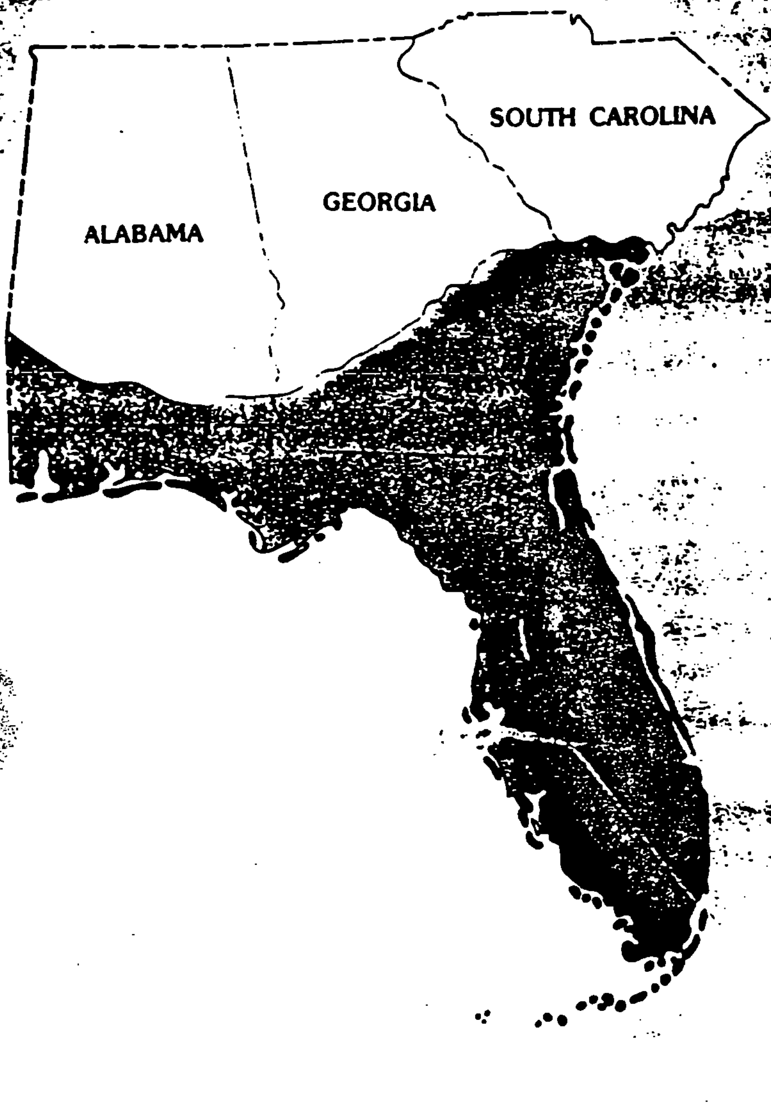
Thickness of the Floridan aquifer system.



LEVY
MARION
1800
VOLUSIA
29°
83°
LAKE
2000
ORANGE
2300
2500
OSCEOLA
28°
POLK
2800
2900
3000
3300
3500
HARDEE
HIGHLANDS
2700
3400
CHARLOTTE
3200
PALM BEACH
HENDRY
27
30°
1500

HYDROGEOLOGIC FRAMEWORK OF THE FLORIDAN AQUIFER SYSTEM IN FLORIDA AND IN PARTS OF GEORGIA, ALABAMA, AND SOUTH CAROLINA

REFERENCE 13



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GENERAL

The Floridan aquifer system is a thick sequence of carbonate rocks generally referred to in the literature as the "Floridan aquifer" in Florida and the "principal artesian aquifer" in Georgia, Alabama, and South Carolina. As defined in this report, the Floridan aquifer system encompasses more of the geologic section and extends over a wider geographic area than either the Floridan or the principal artesian aquifer, as those aquifers have been described in the literature. Figure 7 shows the geologic formations in Florida and southeastern Georgia that were called "principal artesian formations" by Stringfield (1936), those that were included in the "Floridan aquifer" as defined by Parker and others (1955), and those placed in the "principal artesian aquifer" as defined by Stringfield (1966). Subsequent deep drilling and hydraulic testing have shown that highly permeable carbonate rocks extend to deeper stratigraphic horizons than those included in either the "Floridan" or "principal artesian" aquifers as originally described. Accordingly, this author (cited by Franks, 1982) extended the base of the Floridan aquifer downward to include part of the upper Cedar Keys Limestone (fig. 7). Limestone and dolomite beds that commonly occur at the base of the Hawthorn Formation have been included as part of the "Floridan" or "principal artesian" aquifer in most previous reports. However, data collected for the present study show that, except very locally, there are no high-permeability carbonate rocks in the lower part of the Hawthorn Formation that are in direct hydraulic contact with the main body of the Floridan aquifer system.

The Hawthorn Formation was thus excluded from the aquifer system in a report by Miller (1982a) that was one of a series of several interim reports published during the present study. In these interim reports, the aquifer system was called the "Tertiary limestone aquifer system of the Southeastern United States." This cumbersome, albeit more accurate, terminology has subsequently been abandoned, and the aquifer system is referred to in this professional paper as the "Floridan aquifer system" (see Johnston and Bush, 1985 for a more detailed history of the terminology applied to the aquifer system).

The Floridan aquifer system is defined in this report

EPOCH		Stringfield (1936)		Parker and others (1955)		Stringfield (1966)		Miller, in Franks (1982)		Miller (1982 a,c)		This Report	
		Formation	Aquifer	Formation	Aquifer	Formation	Aquifer	Formation	Aquifer	Formation	Aquifer system	Formation	Aquifer system
MIOCENE	Middle	Hawthorn Formation		Hawthorn Formation		Hawthorn Formation		Hawthorn Formation		Hawthorn Formation		Hawthorn Formation	
MIOCENE	Early	Tampa Limestone	Principal artesian formations	Tampa Limestone	Where Permeable	Tampa Limestone	Principal artesian aquifer	Tampa Limestone	Where Permeable	Tampa Limestone	Where Permeable	Tampa Limestone	Where Permeable
OLIGOCENE		Oligocene Limestone		Suwannee Limestone	Floridan aquifer	Suwannee Limestone		Suwannee Limestone	Floridan aquifer	Suwannee Limestone	Tertiary limestone aquifer system	Suwannee Limestone	Floridan aquifer system
EOCENE	Late	Ocala Limestone		Ocala Limestone		Ocala Limestone		Ocala Limestone		Ocala Limestone		Ocala Limestone	
EOCENE	Middle			Avon Park Limestone		Avon Park Limestone		Avon Park-Lake City Limestones		Avon Park-Lake City Limestones		Avon Park Formation	
EOCENE	Middle			Lake City Limestone		Lake City Limestone							
EOCENE	Early					Oldsmar Limestone		Oldsmar Limestone		Oldsmar Limestone		Oldsmar Formation	
PALEOCENE								Cedar Keys Limestone		Cedar Keys Limestone		Cedar Keys Formation	

Figure 7. Comparison of aquifer terminologies.

as a vertically continuous sequence of carbonate rocks of generally high permeability that are mostly of middle and late Tertiary age and hydraulically connected in varying degrees and whose permeability is, in general, an order to several orders of magnitude greater than that of those rocks that bound the system above and below. As plate 2 shows, the Floridan aquifer system includes units of late Paleocene to early Miocene age. Very locally, in the Brunswick, Ga., area, the entire Paleocene section plus a thick sequence of rocks of Late Cretaceous age are part of the aquifer system. In and just downdip of the area where the aquifer system crops out, the entire system consists of one vertically continuous permeable unit. Farther downdip, less permeable carbonate units of subregional extent separate the system into two aquifers, herein called the Upper and Lower Floridan aquifers (fig. 8). These less permeable units may be very leaky to virtually nonleaky, depending on the lithologic character of the rock comprising the unit. Because they lie at considerable depth, the hydrologic character and the importance of the subregional low-permeability units are known from only a few scattered deep test wells. Local low-permeability zones may occur within either the Upper or the Lower Floridan aquifer. In places (for example, southeastern Florida), low-permeability rocks account for slightly more than half of the rocks included in the aquifer system.

Even though the rocks that comprise the base of the Upper Floridan aquifer are not everywhere at the same altitude or geologic horizon or of the same rock type, the presence of a middle confining unit over about two-thirds of the study area has led to a conceptual model for the Floridan aquifer system that consists of two active permeable zones (the Upper and Lower Floridan aquifers) separated by a zone of low permeability (a middle confining unit). Because of this simplified layering scheme, it is necessary to greatly generalize the highly complex sequence of high- and low-permeability rocks that comprise the aquifer system. Local confining beds (see, for example, cross section E-E', pl. 21) are either disregarded because they are regionally unimportant or lumped with one of the major layers. The purpose of the conceptual model, and of the digital computer model derived from it and described by Bush and Johnston (1985) is to portray the major aspects of ground-water flow within the Floridan aquifer system. In like manner, the descrip-

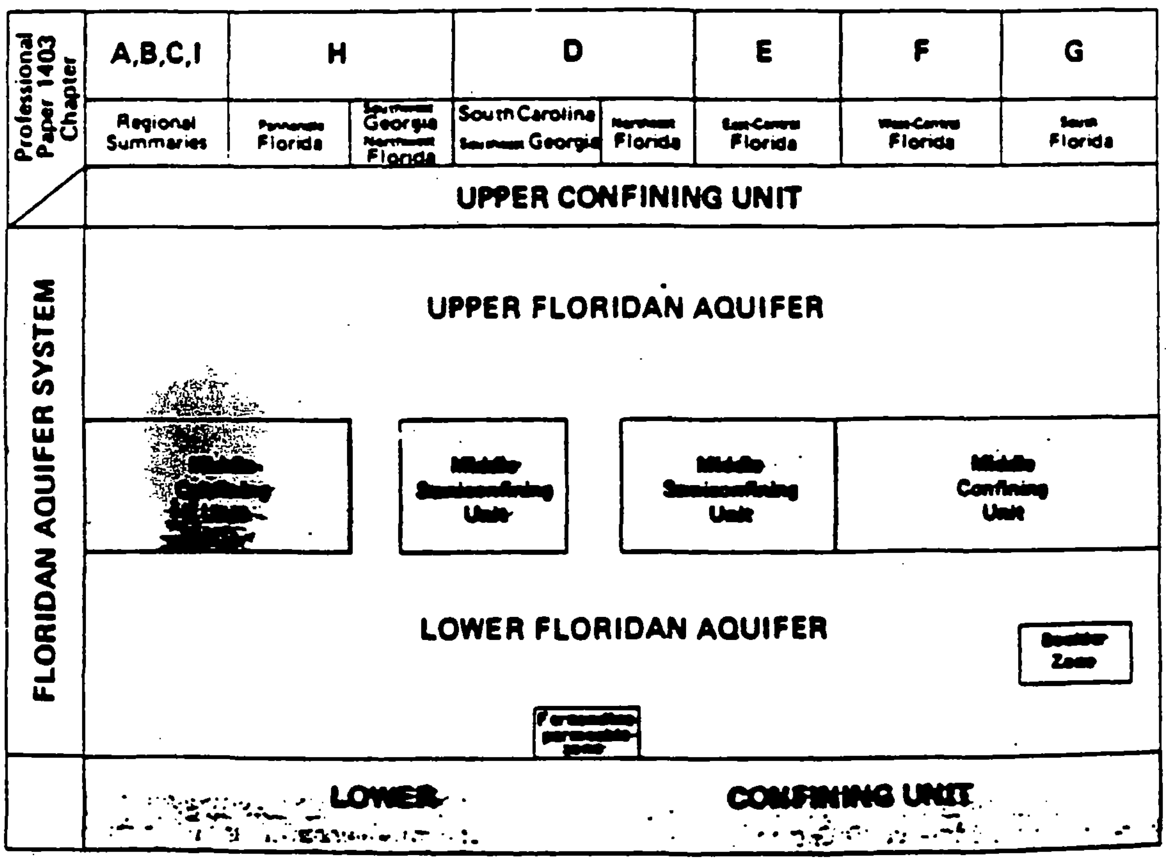


Figure 8. Aquifers and confining units of the Floridan aquifer system.

tion of the aquifer system's geohydrologic framework in this report is intended to show the principal variations in permeability within the aquifer system. In both cases, local anomalies that do not fit with overall (regional) conditions are ignored.

Regionally, the top of the Floridan aquifer system in most places lies at the top of rocks of Oligocene age (Suwannee Limestone) where these strata are preserved. Where Oligocene rocks are absent, the aquifer system's top is generally at the top of upper Eocene rocks (Ocala Limestone). Locally, in eastern panhandle Florida and in west-central peninsular Florida, rocks of early Miocene age (Tampa Limestone) are highly permeable and hydraulically connected to the aquifer system. In places, upper Eocene through lower Miocene rocks are either missing owing to erosion or nondeposition or of low permeability; at these places, rocks of middle Eocene age (Avon Park Formation) mark the top of the aquifer system. It is important to note that there are some places where the upper part of a given formation that comprises the top of the aquifer system consists of low-permeability rocks. At such places, the low-permeability beds are excluded from the aquifer system, and the top of the system is considered to be the top of the uppermost high-permeability carbonate rock. The top of the system, then, may lie within a stratigraphic unit rather than at its top. Because the permeability contrast between the aquifer system and its upper confining unit does not everywhere follow stratigraphic horizons, neither does the top of the aquifer system. Likewise, the top of the aquifer system may locally lie within a limestone unit if the upper part of the limestone consists of low-permeability rock and the lower part is highly permeable.

The time-stratigraphic units or parts of units that mark the top of the Floridan aquifer system at selected localities are shown in figure 9, as well as the time-rock units that comprise the Upper and Lower Floridan aquifers and the units that are considered to represent the aquifer system's base. Figure 9 shows a series of idealized chronostratigraphic columns compiled from well data at several locations in the study area, along with the permeability characteristics of each chronostratigraphic unit at each location. Examination of this figure shows that, in addition to the variations in the top and base of the aquifer system, the degree of permeability varies greatly within the system. Generally (and as figure 9 shows), the aquifer system in most places can be divided into an Upper and Lower Floridan aquifer separated by less-permeable rock. In some places, however, no middle confining unit exists (for example, the Baxley, Ga., and Gainesville, Fla., columns in fig. 9), and the aquifer system is highly permeable throughout its vertical extent. In other places, thick sequences of low-permeability rock occur at several levels within the aquifer system (for example, the Savannah, Ga., and West Palm Beach, Fla., areas in fig. 9), and the several discrete permeable zones of the system may be hydraulically separated.

Regionally, and in a fashion similar to the way in which the top is defined, the base of the aquifer system is defined as the level below which there is no high-permeability carbonate rock. The base of the system is generally either (1) glauconitic, calcareous, argillaceous to arenaceous rock that ranges in age from late Eocene to late Paleocene (fig. 9) or (2) massively bedded anhydrite that commonly occurs in the lower two-thirds of the Paleocene Cedar Keys Formation. Locally, near Brunswick, Ga., micritic limestone and argillaceous limestone of Late Cretaceous (Tayloran) age mark the base of the aquifer system. The permeability of the micritic and argillaceous carbonate rocks, the anhydrite beds, and the various clastic rocks that comprise the base of the system is much less than that of the carbonate rocks above. Regardless of its lithologic character, the lower confining unit, whose top is mapped in this report as the base of the aquifer system, everywhere separates the system from deeper, predominantly clastic aquifers of early Tertiary and Late Cretaceous age.

The upper confining unit of the Floridan aquifer system generally consists of rocks of middle and late Miocene age. Where older rocks such as the lower Miocene Tampa or Oligocene Suwannee Limestones are of low permeability, they are also included in the upper confining unit. In parts of the study area, the upper confining unit has been removed by erosion and the aquifer system either crops out, is covered by only a surficial sand aquifer, or is covered very locally by clayey residuum. Hydraulic conditions within the aquifer system accordingly vary from confined to unconfined. Where thick sequences of less permeable rocks of subregional extent are present within the aquifer system, they divide it into two major aquifers. The uppermost aquifer (Upper Floridan) generally consists of rocks of Oligocene, late Eocene, and late middle Eocene age (fig. 9). The lower aquifer (Lower Floridan) generally consists of rocks of early middle Eocene to late Paleocene age. Where no middle confining unit separates the two aquifers, all the permeable rock comprising the aquifer system is referred to as the Upper Floridan aquifer. The middle confining unit separating the Upper and Lower Floridan aquifers is generally found in the middle part of rocks of middle Eocene age. The less permeable material that comprises the middle confining unit, however, is not everywhere of the same age (fig. 9), nor does it everywhere consist of the same rock type, as a later section of this report discusses in detail.

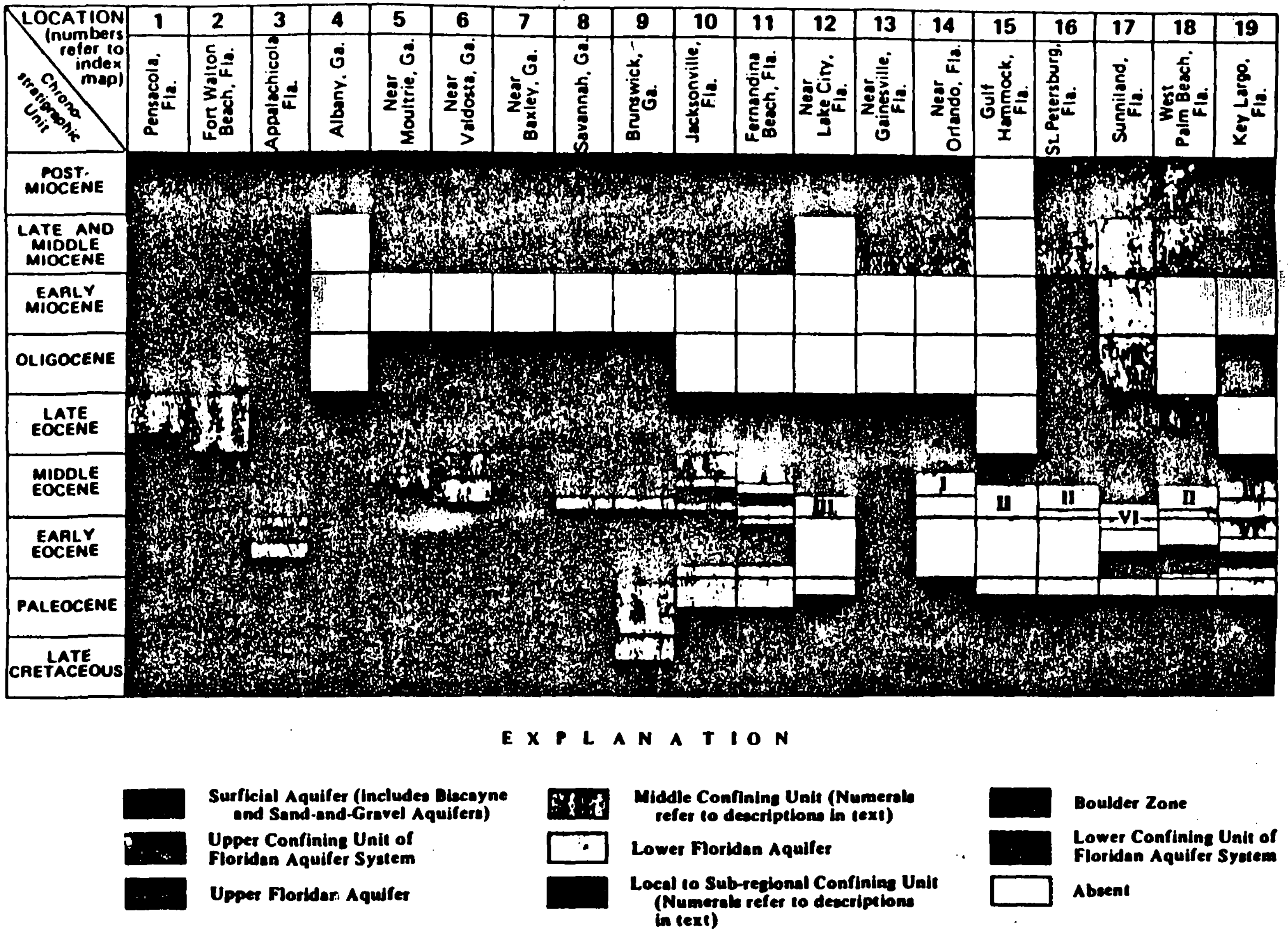


Figure 9. Relation of time-stratigraphic units to the Floridan aquifer system, its component aquifers, and its confining units.

Throughout much of the study area, the water in the Lower Floridan is brackish to saline. The Lower Floridan is moderately to highly porous, and digital simulation indicates that it transmits water sluggishly (see Bush and Johnston, 1985). Little is known about the Lower Floridan aquifer because in most places there is no reason to drill into a deep aquifer containing poor-quality water when an adequate shallower source of good-quality water (the Upper Floridan aquifer) exists.

Local to subregional zones of cavernous permeability occur at several levels within the Floridan aquifer system. The best known of these zones, called the "Boulder Zone" (Kohout, 1965) because of its difficult drilling characteristics, is found in the lower part of rocks of early Eocene age (fig. 9) in southern Florida. Borehole televiewer surveys show that this zone consists of a series of thin to moderately thick horizontal openings connected vertically by fractures, some of which have been opened and enlarged into vertical tubes by solution. The Boulder Zone resembles modern cave systems and is presumed to have formed in a similar fashion—by solution at or above an early Eocene paleowater table. As a result, the transmissivity of the Boulder Zone is extremely high (Meyer, 1974). Other shallower, less extensive cavernous zones are found farther north in the Florida peninsula (Miller, 1979). Where these cavernous zones are developed in the parts of the aquifer system that contain saline water, they are used as receiving zones for underground injection of treated sewage and other industrial wastes.

Within the sequence of rocks that is here treated as an upper confining unit are permeable zones that extend over part of a county or over several counties and that are important local sources of water. These localized artesian aquifers are considered in this report to comprise part of the upper confining unit of the Floridan aquifer system because their permeability is low in comparison with that of the Floridan and because they are of limited extent.

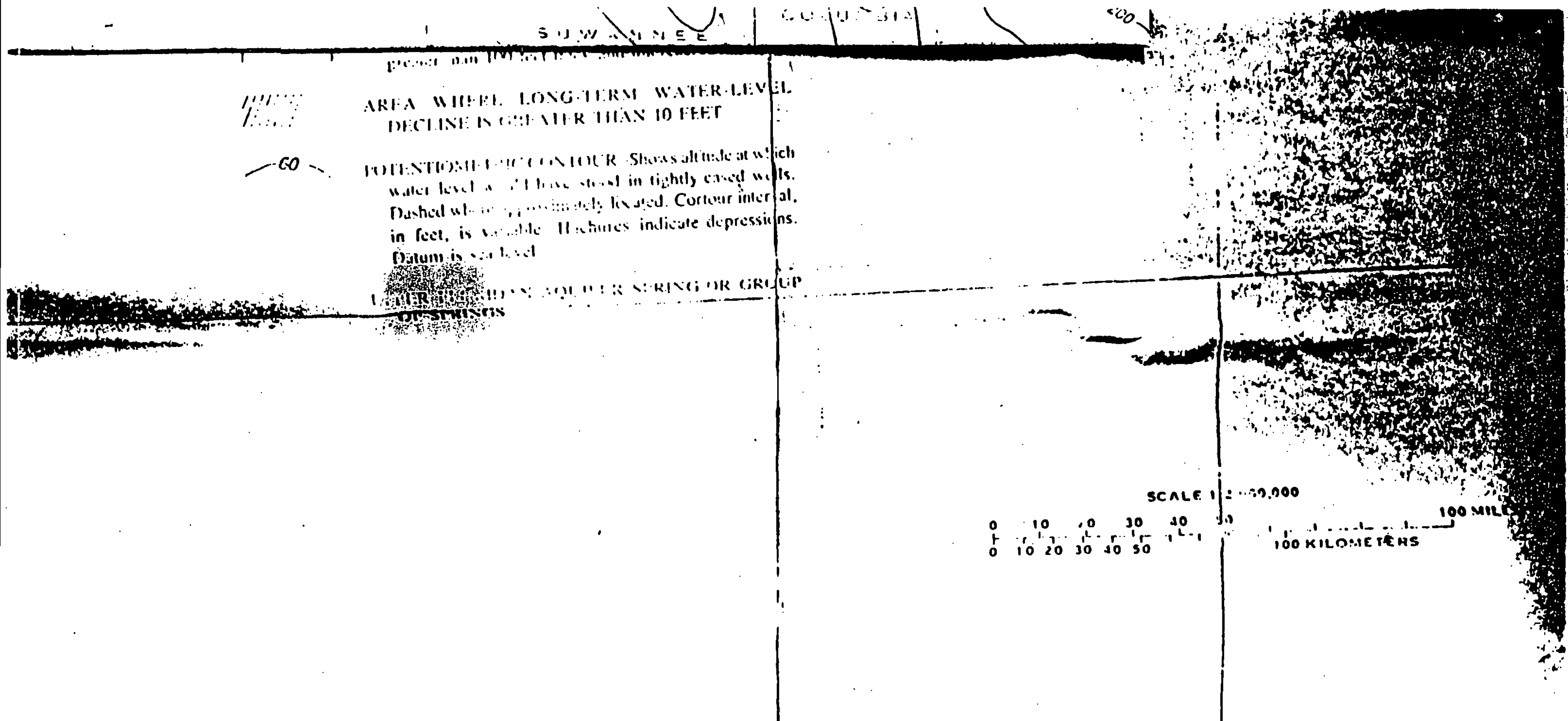
EXTENT

The Floridan aquifer system becomes thin in updip areas where it is interbedded with clastic rocks. The limestones that comprise the aquifer system grade in an updip direction into sandy or argillaceous limestone, which in turn grades into calcareous sand or clay. Still farther updip, these calcareous clastic rocks grade into fully clastic sediments that are stratigraphically equivalent to the aquifer system but are much less permeable than their limestone equivalents. The updip facies change from limestone into clastic rocks and the corresponding decrease in the amount of highly permeable rock in an updip direction are shown by geohydrologic cross-sections A-A', B-B', C-C', D-D' and O'-O'' (pl. 15, 16, 18, 19, 20). The updip limit of the Floridan aquifer system (plate 26) has been arbitrarily placed where the thickness of the system is less than 100 ft and where the clastic rocks interbedded with the limestone make up more than 50 percent of the rock column between the uppermost and lowermost limestone beds that can be shown to be connected downdip. To the north and west of the line shown as the approximate updip limit of the aquifer system, thin beds, lenses, and stringers of limestone may be either connected to the main limestone body or isolated from it because of postdepositional erosion. Although these thin beds and outliers locally yield water in small to moderate amounts, they are not considered in this report to be part of the Floridan aquifer system.

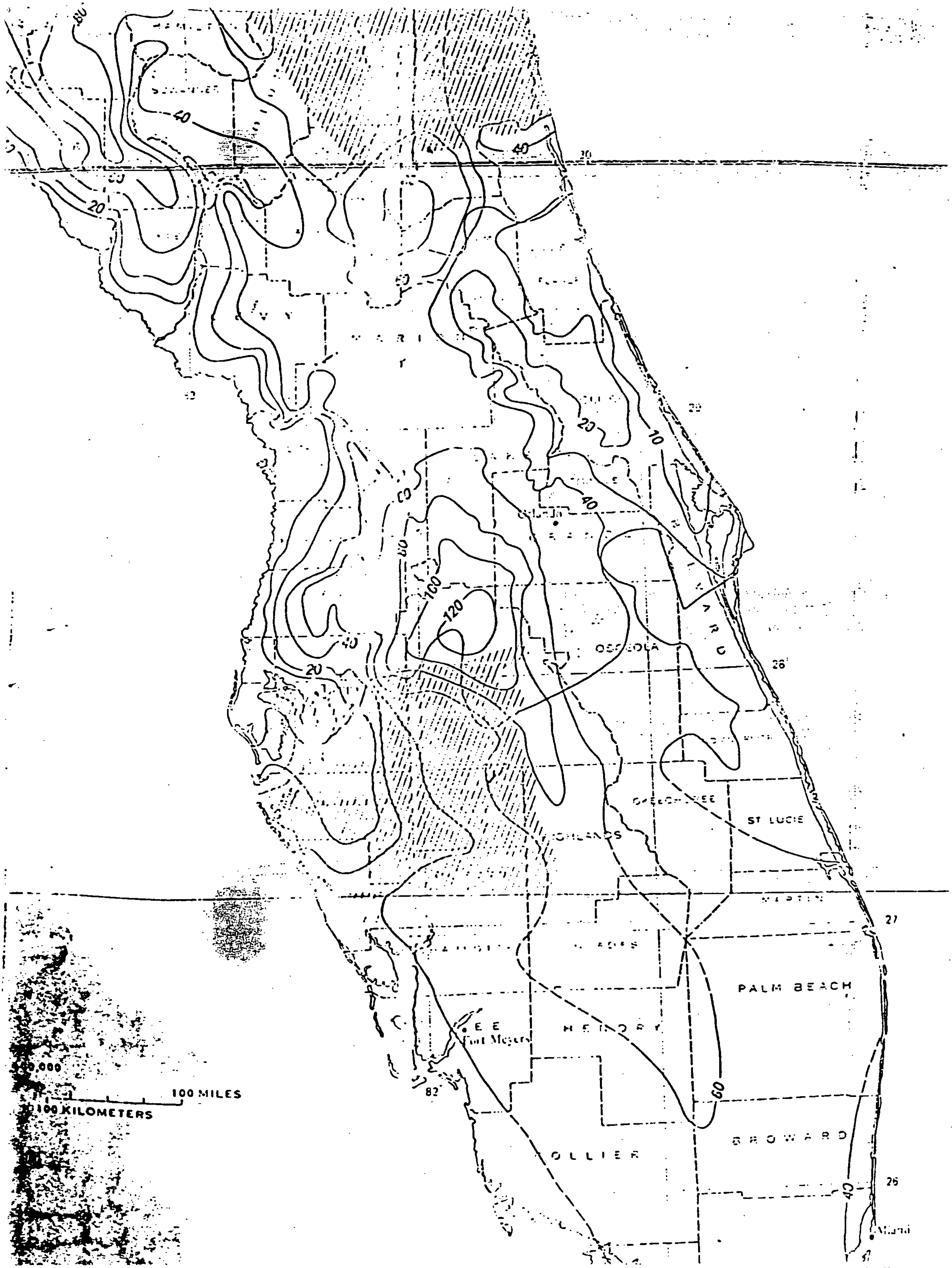
The Floridan aquifer system is known to extend offshore from Georgia (McCollum and Herrick, 1964) and peninsular Florida (Rosenau and others, 1977; Schlee, 1977; Johnston and others, 1982). Because offshore geologic and hydrologic data are sparse, however, the aquifer system is not mapped offshore in this report. The Floridan contains fresh to brackish water in some offshore areas (Johnston and others, 1982), but sparse data on water quality mandate mapping of the aquifer system's freshwater-saltwater interface by indirect methods (Bush and Johnston, 1985; Sprinkle, 1985).

In part of the mapped area in South Carolina, the Upper Floridan aquifer has passed by facies change into low-permeability clastic rocks, and only the Lower Floridan aquifer is present. The effect is that of a pinchout of the Upper Floridan. The approximate area of facies change within the Upper Floridan is shown on plate 26 by a dashed northwest-trending line whose location is based on widely scattered well control. Contours to the northeast of the line represent the top of a middle confining unit that is underlain by the Lower Floridan aquifer at an altitude several hundred feet lower. Other water-bearing limestone units in South Carolina are located northeast of the area mapped in this report, but they are either hydraulically separate from the Floridan aquifer system or their permeability is too low to warrant including them in the system.

A series of faults in southwestern Alabama shown on plate 26 marks the updip limit of the aquifer system. These arcuate faults, which are part of the Gilbertown-Pickens-Pollard fault zone, bound a series of grabens. Movement along these faults has juxtaposed low-permeability clastic rocks within the grabens opposite the permeable limestone that comprises the aquifer system. The north-trending, sinuous, fault-bounded feature in Washington and Mobile Counties,

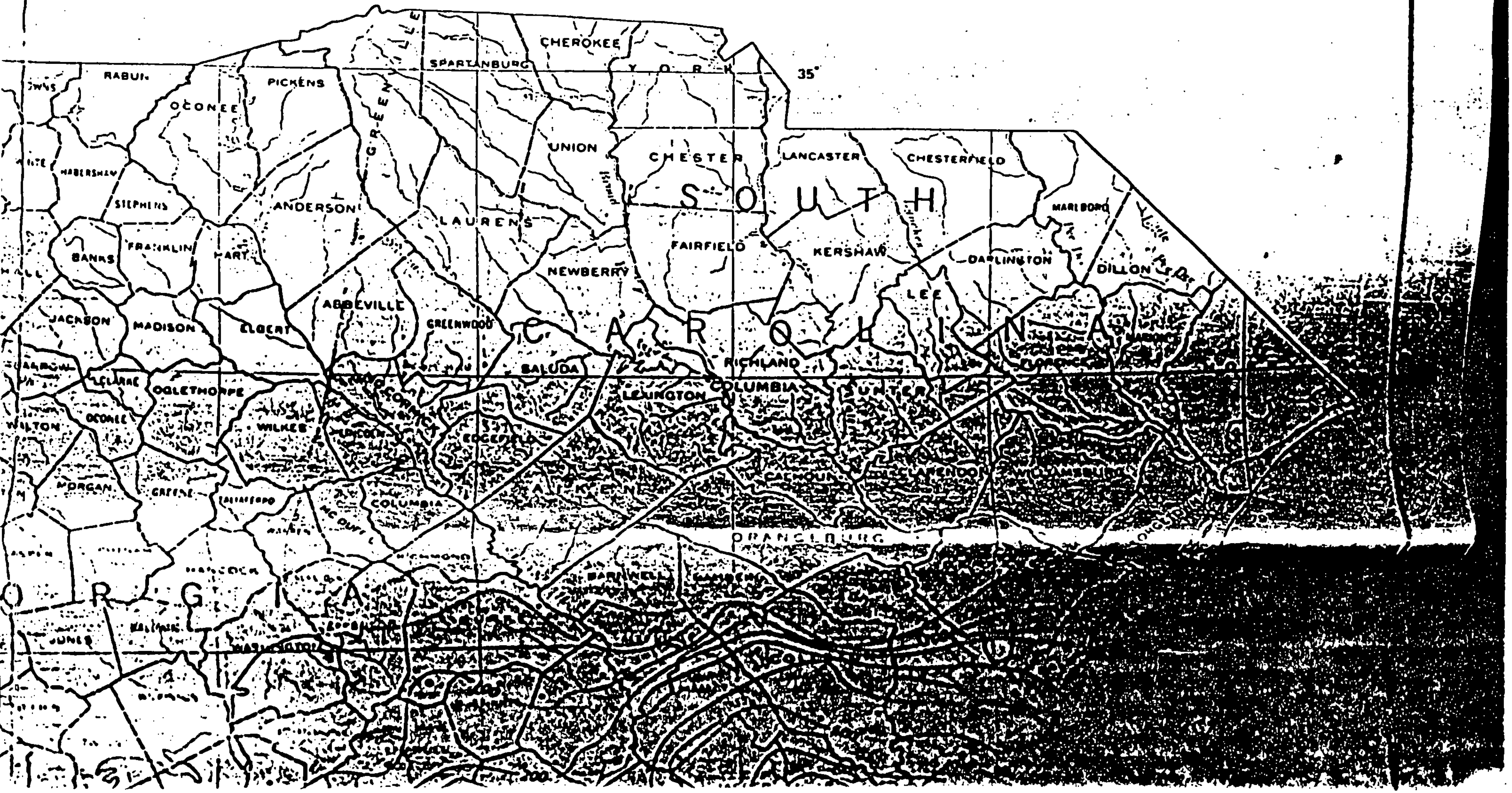


OCCURRENCE OF UNCONFINED, SEMICONFINED AND CONFINED CO
AND POTENTIOMETRIC SURFACE (1980) OF THE UPPER FLORIDAN A



OSCEOLA
OKEECHOBEE
ST LUCIE
HIGHLANDS
MARTIN
PALM BEACH
HENDRY
LEE
Fort Meyers
BROWARD
COLLIER
Miami
100 MILES
100 KILOMETERS
30
28
27
26
82
40
20
10
60
80
100
120

PROFESSIONAL PAPER 1403-B
PLATE 27

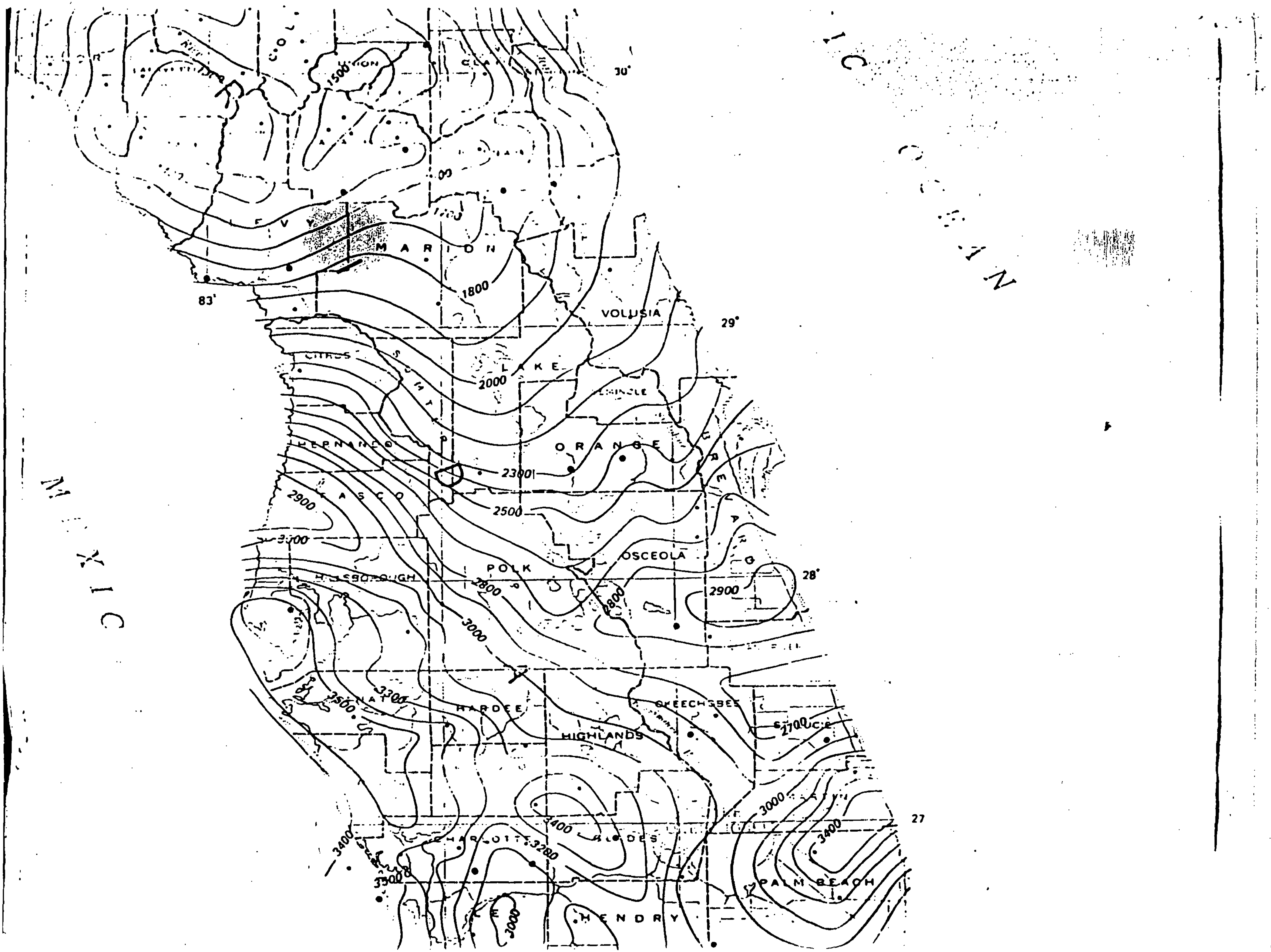


SCALE 1:2,000,000

0 10 20 30 40 50 100 MILES

0 10 20 30 40 50 100 KILOMETERS

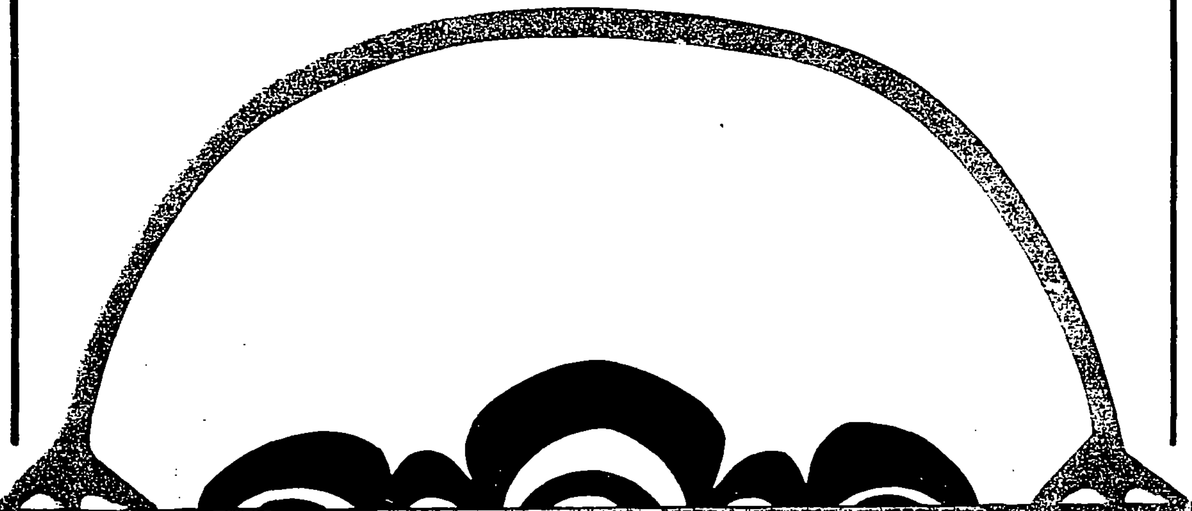
Thickness of the Floridan aquifer system.



UNION
1500
LEVY
MARION
1800
VOLUSIA
LAKE
2000
CITRUS
SEMINOLE
ORANGE
HERNANDO
2300
2500
PASCO
2900
3000
POLK
OSCEOLA
HILLSBOROUGH
2800
2900
3000
3300
3500
HARDEE
OKEECHOBEE
HIGHLANDS
2700
3000
3400
3400
3200
3400
CHARLOTTE
GLADES
3500
PALM BEACH
HENDRY
3000
30°
29°
28°
27
83°

REFERENCE 13A

GROUNDWATER



R. Allan Freeze/John A. Cherry

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Table 2.2 Range of Values of Hydraulic Conductivity and Permeability

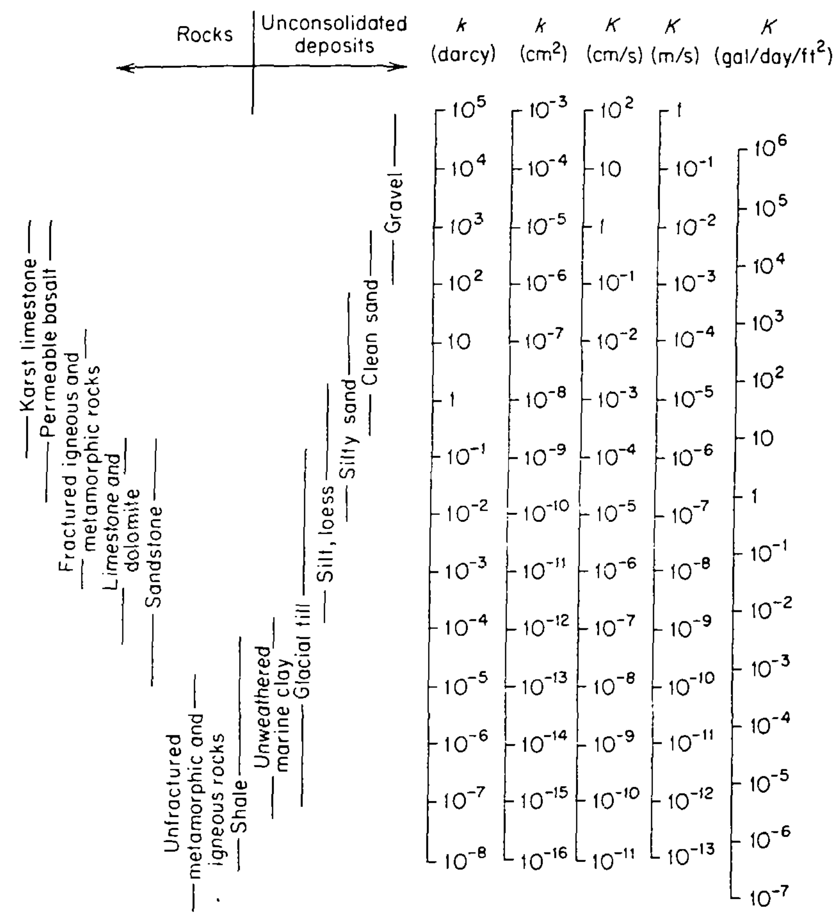

Table 2.3 Conversion Factors for Permeability and Hydraulic Conductivity Units

	Permeability, k*			Hydraulic conductivity, K		
	cm²	ft²	darcy	m/s	ft/s	gal/day/ft²
cm²	1	1.08×10^{-3}	1.01×10^{8}	9.80×10^{2}	3.22×10^{3}	1.85×10^{9}
ft²	9.29×10^{2}	1	9.42×10^{10}	9.11×10^{5}	2.99×10^{6}	1.71×10^{12}
darcy	9.87×10^{-9}	1.06×10^{-11}	1	9.66×10^{-6}	3.17×10^{-5}	1.82×10^{1}
m/s	1.02×10^{-3}	1.10×10^{-6}	1.04×10^{5}	1	3.28	2.12×10^{6}
ft/s	3.11×10^{-4}	3.35×10^{-7}	3.15×10^{4}	3.05×10^{-1}	1	5.74×10^{5}
gal/day/ft²	5.42×10^{-10}	5.83×10^{-13}	5.49×10^{-2}	4.72×10^{-7}	1.74×10^{-6}	1

*To obtain k in ft², multiply k in cm² by 1.08×10^{-3}.

REFERENCE 14

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Orlando Florida
Project Mgr - Phillip Henderson
TDD No F4-8808-22

LOGBOOK REQUIREMENTS
REVISED - NOVEMBER 29, 1988

NOTE: ALL LANGUAGE SHOULD BE FACTUAL AND OBJECTIVE

1. Record on front cover of the Logbook: TDD No., Site Name, Site Location, Project Manager.
2. All entries are made using ink. Draw a single line though errors. Initial and date corrections.
3. Statement of Work Plan, Study Plan, and Safety Plan discussion and distribution to field team with team member signatures.
5. Sign and date each page. Project Manager is to review and sign off on each logbook daily.
6. Document all calibration and pre-operational checks of equipment. Provide serial numbers of equipment used onsite.
7. Provide reference to Sampling Field Sheets for detailed sampling information.
8. Describe sampling locations <u>in detail</u> and document all changes from project planning documents.
9. Provide a site sketch with sample locations and photo locations.
10. Maintain photo log by completing the stamped information at the end of the logbook.
11. If no site representative is on hand to accept the receipt for samples an entry to that effect must be placed in the logbook.
12. Record I.D. numbers of COC and receipt for sample forms used. Also record numbers of destroyed documents.
13. Complete SMO information in the space provided.

Detailed information on samples is recorded on Sampling Field Sheets.

The following people have read and understand the
work plan
Study Plan
Health & Safety Plan
for Chevron Chemical

Andy Spaugh [signature]
Larry Grier [signature]
John Morrow [signature]
Sherry Burken [signature]

Phillip Henderson 1/12/87 E00000

000007

Monday June 12,

0800 - Collect trip blank at motel prior to going to site
CC-TB-01

pH/cond meter 683236
calibration
pH 7 - reading 7.00
pH 4 - reading 4.00

Cond - 3.8 28°C
pH 8.2

0830 - Arrive at site "Affordable Storage"
Hot, humid ~ 78°F

Waiting for Mike Naylor to arrive.

HNU # 4157 Field checked
10.2 probe span 8.9

Phillip Henderson 6/12/89

reading 56 ppm

0845 - Entire site walked over with HNU. No readings above background at any locations.

0910 - Begin installing soil gas probes.

1200 Break for lunch

1300 - Continue installing soil gas probes. Locations of probes are plotted on sample location map. Chemists are recording values off HNU OVA from soil gas probes.

Phillip Henderson 6/12/89 00[illegible]

000004

1600 - Went to North Bros Co. Insulation Distributors located NH ~~East~~ west southeast NH of site. Obtained permission from John Dionne, Branch Manager to collect background samples from grassy area on his property tomorrow AM

Phillip Henderson 6/12/89

Tues June 13,

0745 Arrive at North Bros to collect bkgrd samples.

CC-SS-01 collected at 0755 from SW corner of property 0-3 inches below surface
grey/black fine sand /40% organic matter
Soil Duplicate collected from this surface soil sample.

- CC-SB-01 collected at 0810 from depth of 4½ - 5½ ft bls. grey - rusty brn med sand grn sand.

Phillip Henderson 6/13/89 000005

000006

CC-TW-01 - collected at 0835 from depth of ~ 7ft bls

Conductivity meter 683236 calibrated

pH 7 - reading 7.00

pH 4 - reading 4.00

pH 10 reading 10.00

Temp 28°C

pH ~~8.89~~ (pH) 5.92

Cond 162

CC-SB-06 - Collected at 1000. from 6½ - 7½ ft below surface.

~~11~~/ ~~10~~ppm on HNU. 41549

10 ppm on OVA ~~50901~~ 629329

at top of hole.

sample is fine grn reddish brown sand

Phillip Henderson 6/13/87

with fairly strong pesticide? (petroleum smell)

Sample in bowl 10ppm on OVA

CC-TW-06 - collected at 1120 from ~~12ft~~ bls 9ft bls

6 gallons purged.

28°C pH 8.20 cond 1610

CC-SS-02 collected at 1110, from south side of metal building. From below hole in cinder block wall. Entire ground stained black.

Reading 5 ppm on HNU in hole

Sample collected 0-6 inches below surface, grey - black fine sand with strong petroleum smell

Phillip Henderson 6/13/87

000007

000010

Up to 300 ppm on HNU at top of hole. Nothing in breathing zone. Moderate petroleum smell.

Sample is grey fine sand

CC-TW-05 being collected at same location. Reading on HNU 90-110 ppm at top of well casing.
Collected at 1600
Depth bls 9.5 ft
Temp 86°F or 29°F
pH 5.56
cond 82.4

Phillip Henderson 6/13/89

Wed June 14

0845 Arrive at site. Breezy + warm ~80°F

CC-SB-03 collected from south side of metal building + 8 ft west of opening in side of building where black oily material appears to have poured out in the past.
Depth 5-6 ft bls
sample is fine grey colored sand with strong petroleum smell
>1,000 ppm in top of hole on OVA 629329
Nothing in breathing zone

Phillip Henderson 6/14/89 000011

000012

pH, cond meter # 683236
7 - reading 7.00
4 - reading 4.00
10 - reading 9.94

CC-TW-03 collected at 1025
Temp 27°C
pH 6.39
Cond 863

water is light brown colored, with oily sheen on it.

Depth ~9.5 ft bls

CC-SB-02 collected at 1205 from NE corner of site (Downgradient). sample is buff colored fine sand collected at saturated zone ~12 ft bls.

Phillip Henderson
6/14/89

No reading on Hnu in hole.

CC-TW-02 collected at 1235.
Depth 14 ft bls.
Temp 27°C
pH 6.20
Cond 533

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JOHN DIONNE
Branch Manager
P. O. Box 547817
Orlando, FL 32854-7817
Phone: (407) 293-9221

★ Mr Dionne stated that area along RR tracks to catchment basin and low areas beyond commonly flood during

Phillip Henderson 6/14/89

000013

heavy rains. They have complained in the past about oily debris from Chevron flowing.

10/30/89

Additional Notes: This project and accompanying responsibilities were given to Jerry Jenner on 10/30/89

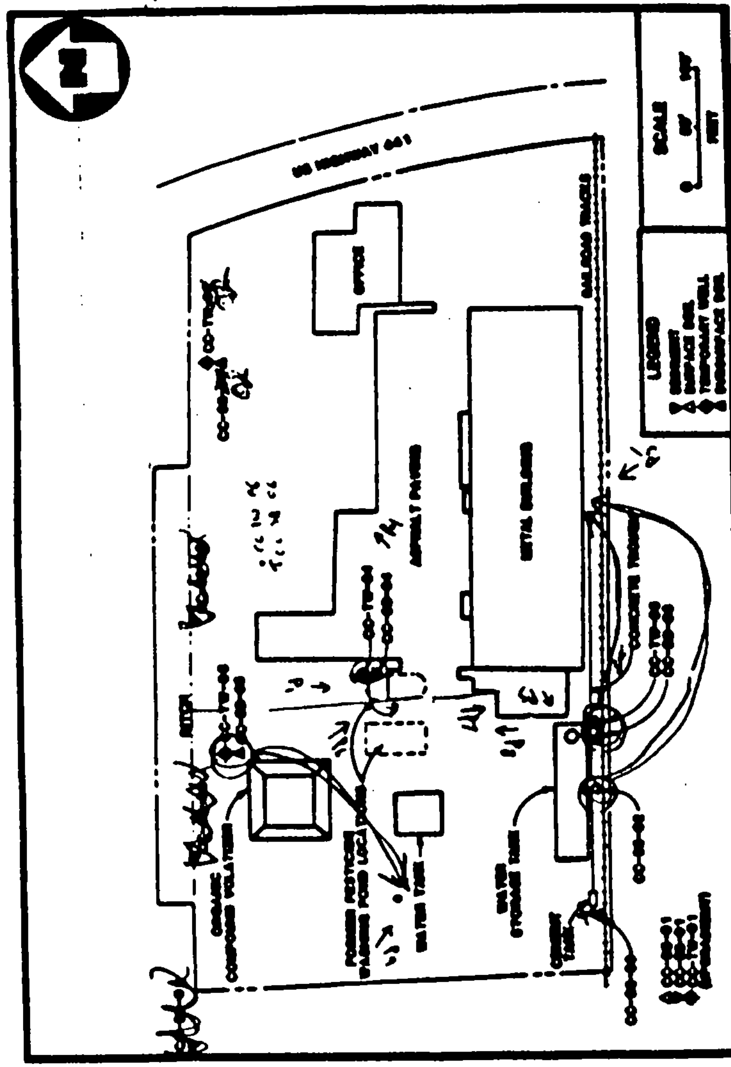
[signature]

11/03/89 I met with Phil Henderson to discuss sample locations. They differ from the study plan (see map insert pg 15). Phil said sediment samples were disregarded. Phil H. also indicated photo positions.

[signature]

Phillip Henderson 6/14/89

Revised sample locations:



SAMPLE LOCATION MAP
CHEVRON CHEMICAL / ORTHO
ORLANDO, ORANGE COUNTY, FLORIDA

REFERENCE 15

NUS CORPORATION AND SUBSIDIARIES — **TELECON NOTE**

CONTROL NO:	DATE: 2-14-90	TIME: 2:50 PM

DISTRIBUTION:

BETWEEN: John Banks	OF: Orlando Utilities Commission Water Dept.	PHONE: (407) 244-8739

AND: Greg Tanner, NUS Corp.

DISCUSSION:

Ground water used to supply Orlando Utilities is obtained from 33 wells (approximate depth at 1320 feet). The nearest well to Chevron is located south east of Lake Ivanhoe at the intersection of Highland Drive and Orange Ave. Water obtained from all wells is combined into this system for distribution to 89,000 homes in Orlando and surrounding counties.

Cynthia K. Gurley

Follow-up call made on February 18, 1992 by Cynthia K. Gurley of BVWST. Mr. Banks is the superintendent of operations at Orlando Utilities. Also, Mr. Banks said the number of homes using their water system had increased to 93,000 homes.

CKG

ACTION ITEMS:

Follow-up call made on May 27, 1992 by Cynthia K. Gurley of BVWST. Water is not used for irrigation of commercial food crops that meet the criteria of a 5-acre minimum. Also, the Orlando Utilities is not in a Wellhead Protection Area.

REFERENCE 16

NUS CORPORATION AN[illegible] **TELECON NOTE**

CONTROL NO:	DATE: 2-14-90	TIME: 3:15 PM

DISTRIBUTION:

BETWEEN:	OF:	PHONE:
Jim Enselmo	Winter Park Utilities	(407) 623-3338

AND: Jerry Janner NUS Corp.

DISCUSSION:
Groundwater is supplied to this municipality via 6 wells with an average depth of 1200 feet. Two of those wells are located 2.2 miles northeast of Chevron at the intersection of Wymore and Lee Road. This utility serves 21,000 homes in the Orlando area. Private wells do exist in this area, however, Mr Enselmo was not aware of any specific wells in the area.

Cynthia K. Gurley.

Follow-up call made on February 18,1992 by Cynthia K. Gurley of BVWST.

Mr. Enselmo is the manager at the Winter Park Utilities.

CKG

ACTION ITEMS:
Follow-up call made on May 27, 1992 by Cynthia K. Gurley of BVWST. Water is not used for irrigation of commercial food crops that meet the criteria of a 5-acre minimum. Also, the Winter Park Utilities is not in a Wellhead Protection Area.

B&V WASTE SCIENCE AND TECHNOLOGY CORP.

MEMORANDUM

BVWST Project 52013.040
BVWST File E.1
March 9, 1992

Chevron Chemical Company, Inc./Ortho Division
To locate private well users in the area.

Mr. Stewart located all the private wells on a 4 mile radius map, I provided. Keller Music (approximately 5 employees) is located 1 mile south from the site. 132 homes are located between 2-3 miles northwest of the site, and 440 homes are located between 3-4 miles northwest of the site.

The private wells are 125 feet to 200 feet below land surface.

The private wells are located on Reference 8.

Cynthia C. Gurley

B & V WASTE SCIENCE & TECHNOLOGY CORP.

1117 PERIMETER CENTER WEST
SUITE W-212
ATLANTA, GEORGIA 30338
TEL (404) 392-9227
FAX: (404) 392-9289

BVWST Project 52013.040
BVWST File
February 13, 1992

Mr. David Stewart
Central Florida Well Drillers
3720 North Orange Blossom Trail
Orlando, Florida 32804

Subject: To locate private drinking water wells in the area

Dear Mr. Stewart:

I have enclosed four U.S.G.S. topographic maps of the area that is being investigated by the Environmental Protection Agency. I have indicated on the map the center of the study area. The investigation is taking into account a four mile radius from the center of the study area.

As per our conversation on February 12, 1992, please circle or indicate all the area residents which utilize private wells for potable water on the maps. Also, if you have any additional information (latitude and longitude of wells or depths), it would be greatly appreciated.

Should you have any questions, please don't hesitate to call.

Very truly yours,

B&V WASTE SCIENCE AND TECHNOLOGY CORP.

Cynthia K. Gurley

Cynthia K. Gurley
Project Scientist

jv
Enclosure

The well for Keller Music is approx. one mile South of Center. Most of other wells are in Lockhart Area as circled. The well casing are normally 80' to 100' and the well depths are 125' to 200'.
Keller Music - approximately 5 employees.

[For definitions of terms and meanings of symbols, see text]

State / County / Place and [In Selected States] County Subdivision	Persons in households	All households	Family households			Nonfamily households	Householder living alone			Persons per—		Persons in group quarters		
			Total	Married-couple family	Female householder, no husband present	Total	Total	65 years and over Total	65 years and over Female	Household	Family	Total	Institutionalized persons	Other persons in group quarters
The State	12 630 485	5 134 869	3 511 825	2 791 734	548 586	1 623 044	1 309 864	591 468	456 603	2.46	2.98	307 461	173 637	133 824
COUNTY														
Alachua County	170 802	71 258	41 151	30 361	8 562	30 107	19 995	4 614	3 623	2.40	3.00	10 794	2 763	8 031
Baker County	16 647	5 554	4 511	3 639	689	1 043	875	360	277	3.00	3.36	1 839	1 787	52
Bay County	124 113	48 938	35 608	28 753	5 432	13 330	11 272	3 956	3 009	2.54	2.99	2 881	1 526	1 355
Bradford County	19 303	7 193	5 470	4 349	888	1 723	1 464	688	515	2.68	3.10	3 212	3 178	34
Brevard County	392 331	161 365	113 149	93 552	14 671	48 216	38 224	15 059	11 364	2.43	2.88	6 647	3 618	3 029
Broward County	1 239 535	528 442	335 022	263 624	52 923	193 420	155 961	75 919	59 732	2.35	2.91	15 953	11 419	4 534
Calhoun County	9 998	3 793	2 784	2 148	506	1 009	920	474	358	2.64	3.13	1 013	1 013	–
Charlotte County	108 214	48 433	35 325	31 392	2 914	13 108	11 143	7 263	5 402	2.23	2.59	2 761	2 542	219
Citrus County	92 134	40 573	29 679	25 990	2 752	10 894	9 387	5 714	4 128	2.27	2.64	1 381	1 205	176
Clay County	104 773	36 663	29 643	25 251	3 323	7 020	5 555	1 725	1 325	2.86	3.18	1 213	1 138	75
Collier County	146 534	61 703	43 795	37 492	4 386	17 908	13 929	6 817	5 130	2.41	2.80	3 565	1 164	2 401
Columbia County	41 604	15 611	11 516	8 929	2 033	4 095	3 548	1 412	1 035	2.67	3.13	1 009	618	391
Dade County	1 904 375	692 355	481 263	342 515	103 371	211 092	172 164	69 425	52 059	2.75	3.29	32 719	20 111	12 608
DeSoto County	21 517	8 222	6 046	4 830	893	2 176	1 820	1 018	745	2.62	3.02	2 348	1 802	546
Dixie County	10 021	3 916	2 894	2 369	390	1 022	876	398	284	2.56	2.99	564	550	14
Duval County	654 003	257 245	175 353	131 780	35 249	81 892	66 906	21 887	17 246	2.54	3.10	18 968	6 466	12 502
Escambia County	253 191	98 606	70 066	53 113	13 982	28 540	23 300	8 411	6 665	2.57	3.05	9 607	2 731	6 876
Flagler County	28 522	11 880	9 168	8 050	844	2 712	2 250	1 150	836	2.40	2.72	179	102	77
Franklin County	8 768	3 628	2 586	2 117	348	1 042	923	476	343	2.42	2.88	199	167	32
Gadsden County	38 838	13 405	10 139	6 522	3 016	3 266	2 886	1 321	1 021	2.90	3.39	2 267	2 103	164
Gilchrist County	8 712	3 284	2 550	2 125	308	734	624	302	219	2.65	3.02	955	923	32
Glades County	7 401	2 885	2 119	1 807	202	766	638	336	200	2.57	2.98	190	49	141
Gulf County	11 259	4 324	3 242	2 622	478	1 082	977	494	394	2.56	3.00	435	425	10
Hamilton County	9 795	3 488	2 636	1 870	643	852	776	351	257	2.81	3.30	1 135	1 086	49
Hardee County	18 874	6 391	5 076	4 118	667	1 315	1 124	649	490	2.95	3.31	625	155	470
Hendry County	25 153	8 402	6 533	5 099	1 017	1 869	1 478	607	422	2.99	3.36	620	377	243
Hernando County	100 147	42 300	32 567	28 750	2 923	9 733	8 315	5 185	3 824	2.37	2.80	968	860	108
Highlands County	67 369	29 544	21 398	18 721	2 075	8 146	7 147	4 657	3 524	2.28	2.67	1 063	699	364
Hillsborough County	815 620	324 872	219 585	169 443	38 806	105 287	82 246	26 405	20 296	2.51	3.04	18 434	7 881	10 553
Holmes County	14 834	5 800	4 317	3 509	649	1 483	1 370	730	571	2.56	3.02	944	878	66
Indian River County	88 774	38 057	27 182	23 205	2 976	10 875	9 091	5 063	3 834	2.33	2.73	1 434	1 039	395
Jackson County	38 974	14 465	10 504	8 177	1 863	3 961	3 666	1 834	1 539	2.56	3.07	4 401	3 282	1 119
Jefferson County	11 091	3 982	2 980	2 154	664	1 002	882	439	330	2.70	3.29	205	198	7
Lafayette County	4 721	1 721	1 344	1 101	185	377	338	183	129	2.74	3.14	857	755	102
Lake County	149 303	63 616	46 258	39 553	5 111	17 358	15 113	9 315	7 119	2.35	2.75	2 801	1 702	1 099
Lee County	329 784	140 124	99 698	84 393	11 423	40 426	32 280	17 056	12 979	2.35	2.74	5 329	3 154	2 175
Leon County	181 567	74 826	45 118	33 804	9 228	29 710	20 198	4 543	3 627	2.43	3.02	10 928	2 695	8 231
Levy County	25 402	10 079	7 421	5 979	1 115	2 658	2 259	1 183	825	2.52	2.94	521	443	78
Liberty County	4 592	1 706	1 286	1 031	193	420	374	188	137	2.69	3.15	977	977	–
Madison County	15 213	5 522	4 103	2 924	947	1 419	1 282	682	523	2.75	3.25	1 356	1 281	75
Manatee County	208 475	91 080	61 659	51 711	7 619	29 401	24 590	14 547	11 515	2.29	2.74	3 232	2 465	767
Marion County	190 896	78 177	57 039	46 800	8 023	21 138	17 924	9 192	6 700	2.44	2.85	3 937	3 513	424
Martin County	98 256	43 022	30 060	26 090	2 816	12 962	10 756	6 110	4 676	2.28	2.69	2 644	2 437	207
Monroe County	75 197	33 583	20 598	17 407	2 158	12 985	9 331	2 785	1 780	2.24	2.73	2 827	476	2 351
Nassau County	43 472	16 192	12 158	10 068	1 532	4 034	3 438	1 320	996	2.68	3.13	469	344	125
Okaloosa County	138 561	53 313	39 703	33 242	5 050	13 610	11 161	3 255	2 517	2.60	3.03	5 225	2 477	2 748
Okeechobee County	28 084	10 214	7 695	6 291	954	2 519	1 953	871	610	2.75	3.11	1 543	514	1 029
Orange County	653 343	254 852	171 128	132 081	29 574	83 724	60 340	17 702	14 154	2.56	3.07	24 148	8 068	16 080
Osceola County	105 070	39 150	29 107	23 917	3 736	10 043	7 528	3 270	2 528	2.68	3.07	2 658	1 087	1 571
Palm Beach County	847 780	365 558	242 273	199 308	31 514	123 285	100 419	52 682	41 559	2.32	2.81	15 738	9 605	6 133
Pasco County	274 979	121 674	85 672	73 814	8 885	36 002	31 221	20 076	15 380	2.26	2.68	6 152	3 368	2 784
Pinellas County	830 111	380 635	236 554	191 029	35 742	144 081	121 311	64 868	51 130	2.18	2.73	21 548	16 086	5 462
Polk County	395 256	155 969	114 554	92 670	16 846	41 415	34 952	17 204	13 381	2.53	2.98	10 126	6 824	3 302
Putnam County	63 918	25 070	18 372	14 593	2 986	6 698	5 802	2 914	2 114	2.55	3.00	1 152	845	307
St. Johns County	81 464	33 426	23 260	19 185	3 110	10 166	8 046	3 336	2 529	2.44	2.90	2 365	1 335	1 030
St. Lucie County	147 761	58 174	43 317	35 610	5 754	14 857	11 782	6 094	4 495	2.54	2.91	2 410	1 569	841
Santa Rosa County	80 259	29 900	23 336	19 491	2 935	6 564	5 483	1 816	1 394	2.68	3.08	1 349	598	751
Sarasota County	273 016	125 493	83 732	71 914	9 223	41 761	34 718	20 768	16 491	2.18	2.61	4 790	3 604	1 186
Seminole County	284 673	107 657	77 365	63 074	10 899	30 292	22 876	6 934	5 447	2.64	3.11	2 856	2 167	689
Sumter County	29 830	12 119	8 893	7 235	1 318	3 226	2 831	1 575	1 083	2.46	2.88	1 747	1 520	227
Suwannee County	26 235	10 034	7 429	5 949	1 135	2 605	2 328	1 259	987	2.61	3.07	545	458	87
Taylor County	17 059	6 401	4 838	3 827	778	1 563	1 389	642	476	2.67	3.10	52	47	5
Union County	7 748	2 958	2 106	1 683	330	852	404	236	185	2.61	3.31	2 504	2 476	28
Volusia County	357 380	153 416	102 880	84 016	14 522	50 536	40 492	21 085	16 280	2.33	2.80	13 332	6 054	7 278
Wakulla County	14 042	5 210	4 040	3 192	649	1 170	980	399	283	2.70	3.07	160	157	3
Walton County	27 534	11 294	8 142	6 659	1 146	3 152	2 770	1 232	913	2.44	2.80	226	212	14
Washington County	16 454	6 443	4 828	3 919	717	1 615	1 492	806	608	2.55	3.00	461	449	12
PLACE AND COUNTY SUBDIVISION														
Aberdeen CDP, Palm Beach County	2 572	1 072	913	869	30	159	133	68	54	2.40	2.80	–	–	–
Alachua city, Alachua County	4 508	1 637	1 255	823	384	382	329	113	86	2.75	3.16	21	–	21
Alford town, Jackson County	464	182	139	109	25	43	40	25	20	2.55	2.94	8	–	8
Altamonte Springs city, Seminole County	34 615	15 432	8 654	6 614	1 547	6 778	5 032	878	703	2.24	2.91	364	349	15
Altha town, Calhoun County	497	193	128	93	28	65	60	38	32	2.58	3.23	–	–	–
Alva CDP, Lee County	1 036	430	316	271	29	114	93	38	37	2.41	2.80	–	–	–
Andover CDP, Dade County	6 251	2 736	1 602	1 190	356	1 134	973	406	303	2.28	2.89	–	–	–
Anna Maria city, Manatee County	1 744	820	540	487	33	280	220	123	64	2.13	2.58	–	–	–
Apalachicola city, Franklin County	2 552	1 034	690	486	186	344	301	167	133	2.47	3.05	50	48	2
Apollo Beach CDP, Hillsborough County	5 990	2 452	1 906	1 676	168	546	434	213	166	2.44	2.75	36	–	36
Apopka city, Orange County	13 446	5 112	3 822	3 001	614	1 290	968	314	234	2.63	2.99	64	46	18
Arcadia city, De Soto County	6 112	2 359	1 584	1 094	402	785	674	404	322	2.59	3.16	376	154	222
Archer city, Alachua County	1 372	501	344	227	102	157	136	68	55	2.74	3.37	–	–	–
Asbury Lake CDP, Clay County	2 072	710	645	589	35	65	53	19	12	2.92	3.00	–	–	–
Astatula town, Lake County	977	361	295	260	23	66	57	30	24	2.71	3.01	–	–	–
Astor CDP, Lake County	1 273	595	416	380	46	179	153	92	61	2.14	2.80	4	4	–
Atlantic Beach city, Duval County	11 636	4 541	3 139	2 446	551	1 402	1 094	254	206	2.56	3.03	–	–	–
Atlantis city, Palm Beach County	1 653	775	595	549	27	180	170	137	119	2.13	2.46	–	–	–
Auburndale city, Polk County	8 733	3 385	2 501	1 954	437	884	737	381	314	2.58	3.00	125	115	10
Aventura CDP, Dade County	14 808	8 650	4 447	3 906	412	4 482	4 030	2 636	2 096	1.88	2.25	5	–	5

TP84 [POSTSCRIPT] CPH112 CENSUS90 72582000 06/23/91 3:04 PM MACHINE: C DATA:CENSUS90*PH1TP5DAT12 06/23/91 14:52:57 OUTPUT:ONSITE-P0002 PAGE: 79
TSP:CENSUS90*92 06/23/91 14:53:13 UTF:CENSUS90*92 06/23/91 14:53:13 META:CENSUS90*PH1TABLES12 06/23/91 15:01:15

TELEPHONE MEMORANDUM

Site Assessment
Chevron Chemicals

BVWST Project 52013.040
BVWST File E.1
July 16, 1992
3:20 p.m.

Companies Serviced by Orlando Utilities
for Commercial Food Preparation

To:	Howard Smith
Company:	Orlando Utilities Commission Water Department
Phone No.:	(407) 244-8739
Recorded by:	Cynthia K. Gurley/BVWST CKG 7-16-92.

Mr. Smith is the director of water production division at Orlando Utilities. There are several companies located in the Orlando area that are serviced by the water department for commercial food preparation. These companies include: Polar Cup, Inc., Andrea Quality Cheesecake, and Florida Coca-Cola Bottling Canned Products Division. The address for each of these companies is located in Reference 20.

Reference 20

1991 Directory of Florida Industries

54th Edition

Published By
Florida Chamber of Commerce
Business Center
Post Office Box 11309
Tallahassee, Florida 32302-3309
(904) 222-2831

FLORIDA CHAMBER
Business Center

Plastic Tubing Industries, Inc
750 Vulcan Road — Orlando
Mail: P. O. Box 607356
Fl 32860-7356
Michael Maroschak, President
Douglas Everson
Scott Dunlee
PH (407) 298-5121 — Import & Export
Fax. (407) 578-9393
Toll-Free: 1-800-432-0048
Emp: 25
Corrugated plastic drainage pipe 3084
Plastic tubing 3089

Polar Cup, Inc
Mail: 4401 Curry Ford Rd. — Orlando
Fl 32812-2708
Dino D'Errico, Manager
PH (305) 282-5571
Emp: 15
Frozen lemonade 2038

Pounds Motor Co, Inc.
162 W Plant Street — Winter Garden
Mail: P. O Box 770248
Fl 34777-0248
James H. Pounds, President
Russell S. Pounds, Sec/Treas
PH (407) 656-1352 — Export
Emp: 35
Agric. machinery 3523

Practical Engineering
Mail: P.O. Box 3057 — Winter Park
Fl 32790-3057
Arnold Stein, Vice Presi
PH (407) 629-9463
Emp: 0
Business consulting 8748

Precision Metal Services, Inc.
Mail: 814 W. Church St. — Orlando
Fl 32805-2212
Jack H. Brush, Pres
Laurie J. Conley, Sec/Treas
PH (407) 843-3682
Fax: (407) 843-0206
Toll-Free: 1-800-940-0205
Emp. 13
Sheet metal chassis, parts, painting 3449
Heat sinks 3431
Electronic training devices 3469
Mail box components 3469

Precision Meters, Inc/Certainteed Corp. & St. Gobain
Mail: 11100 Astronaut Boulevard — Orlando
Fl 32821-9280
Eddie Anderson, President
PH (407) 851-4470 — Export
Emp: 33
Water Meters - all types 3824

Presentations South, Inc.
Mail: 4249 L. B. McLeod Rd. — Orlando
Fl 32811-5699
Robert Buck
PH (407) 843-2535 — Import & Export
Emp: 35
Exhibits, amusements, museums 3999
Attractions 3999
Custom millwork 3449

Printing Industries Of Florida, Inc.
Mail: 4205 Edgewater Dr. — Orlando
Fl 32804-2297
J. Penrod Jones
PH (407) 290-5801
Emp: 6
Printing 2759

Printing Service
Mail: 1315 N. Mills Ave. — Orlando
Fl 32803-2542
George Dahlquist, Owner
PH (305) 896-2294
Emp. 10
Commercial printing 2759

Pro Chem Products Inc
1340 West Central — Orlando
Mail: P. O Box 5127
Fl 32855-5127
Paul Hinderliter, Pres,Sales
Muriel Hinderliter, Secy-Treas
PH (305) 425-5533
Emp: 12
Upholstery shampoo,car wax, dertgnt 2842

Products By Cameo, Inc.
Mail: 1620 Premier Row — Orlando
Fl 32809-5712
Leonard Schmidt
PH (407) 857-1620 — Export
Emp: 30
Crafts 3944
Textile paints 2851
Needle punch 2395

Professional Contacts, Inc.
Mail. 3185 S. Conway Rd. Suite E
Fl 32812-7395 — Orlando
George Johnson, President
Charles Doyle, Vice Pres
PH (407) 273-2599
Emp. 35
Opthalmic goods 3851

Professional Equipment Resource, Inc.
Mail. 6757 Edgewater Commerce Pkwy
Fl 32810-4278 — Orlando
Charles Halgren, President
PH (407) 297-9999 — Import & Export
Fax: (407) 297-6818
Toll-Free: 1-800-654-5171
Emp: 10
New and reconditioned dental equipment 3843

Progressive Communications, Inc.
Mail: 1676 E Semoran Blvd. — Apopka
Fl 32703-5697
Bob Czesnakowicz, President
PH (407) 880-0111
Emp: 45
Printing 2759

Erwin F. Puch Manufacturing Corp.
Mail: 1239 W. Columbia St. — Orlando
Fl 32805-3834
Erwin Puch, Jr., Owner
PH (407) 425-3965
Emp: 3
Custom mfg. of small parts 3599

Qual-Tech, Inc
Mail: 2580 S Orange Blossom Trail
Fl 32805-5455 — Orlando
John J Davis, President
PH (305) 843-3290
Emp: 10
Cust plastic fab & vacuum forming 3089

Quality Assurance Institute
Mail: 7575 Dr. Phillips Blvd, Ste 350
Fl 32819-7273 — Orlando
William Perry
Debra Melnick
PH (407) 363-1111 — Export
Fax: (407) 363-1112
Emp: 12
Computer software svcs 7371
Educational seminars on quality assurance 8748
Promotional products for quality assurance 8734

Qualogy
Mail: 87 E Michigan St — Orlando
Fl 32806-4416
PH (407) 423-1047
Emp. 5
(computing equipment electronic) 3577

Quebelor Printing, Inc.
Mail: 6300 Hazeltine Nat'l Dr #108
Fl 32822-5109 — Orlando
Bob D'Angelo, Gen Mgr
PH (407) 851-3681
Emp: 42
Computer graphics 3577

Quemco Laboratories Inc.
Mail: P.O. Box 585634 — Orlando
Fl 32858-5634
T. Conrado, President
PH (407) 295-8218
Emp: 3
Water treatment compounds 2899
Janitorial treatment compounds 2899

Ram-Lin Custom Trailers, Inc
Mail: 9388 Sidney Hayes Rd. — Orlando
Fl 32824-8105
Craig Corbett, Gen Mgr
PH (305) 851-1144
Emp. 11
Boat & utility trailers 3792

Randall Made Knives
Mail: P. O Box 1988 — Orlando
Fl 32802-1988
Gary T. Randall
PH (407) 855-8075 — Import & Export
Fax: (407) 855-9054
Emp: 17
Sporting sheath knives 3421

Rays Furniture Frame Mfg.
Mail: 2812 Apopka Blvd. — Apopka
Fl 32703-9347
Gary Newton
Penny Newton
PH (407) 299-7411
Emp: 3
Furniture frames 2426

Rebah Fabrication, Inc.
Mail: 11300 Space Blvd. — Orlando
Fl 32821-9265
Joseph Haber, President
Pamela L. Burgess, Cont
PH (407) 857-3232
Fax: (407) 240-8312
Emp: 10
Custom metal fabrication 3499
Welding 3548

Reddy Creek Utilities Co
Mail: 9003 Lake Mabel Dr. — Orlando
Fl 32819-8804
Jack Rabon
PH (407) 824-4024
Emp. 0
Subassemblies and electronic components nec 3679

Regal Marine Industries, Inc.
Mail: 2300 Jetport Dr. — Orlando
Fl 32809-7829
Paul Kuck, President
PH (407) 851-4360 — Export
Emp: 500
Boats & marine products 3731
Powerboats 18' - 36' in length 3842
Whirlpool baths (spas) 3842

Repco Incorporated
2421 N. Orange Blossom Trail — Orlando
Mail: P. O. Box 7065
Fl 32804
R. Wayne Nelson, President
William H. Cole, Vp Mktg/Sl
John Long, Vp Finance
PH (407) 843-8484 — Import & Export
Emp: 275
Radio communication equipment 3669
Telemetry 3812
Security systems 3699

Revmaster Machine
Mail: 5358 Old Wint
Fl 32811-1521
Robert W. Williams, (
PH (407) 295-7691
Emp: 11
Machine shop work

Rhema Corp Of Orla
Mail: 10901 Rhema
Fl 32821-9257
Mark Mosher, Presid
Pat Mosher, Vice Pre
Jeff Recker, Ex Vp
PH (305) 885-1290
Emp: 50
Aluminum windows &

Rinker Materials Cor
Mail: P. O. Box 323
Fl 32790-0323
Bernard J. Huguenot
Charles R. Jameson
PH (407) 671-2134
Emp: 37
Ready mixed concret
Concrete blocks

Rinker Materials Co
Mail: P. O. Box 607
Fl 32860-7734
Mark A. Chernega, D
Chuck Griffin, Dis Sls
Carla McMullen, Per
PH (407) 298-3870
Fax: (407) 299-950
Emp: 400
Ready mixed concret
Concrete block
Cement

Rinker Materials Co
Mail: P. O. Box 607
Fl 32860-738
Charles R. Jameson,
Tim Holt, Oper Mgr
PH (407) 293-8310
Emp: 31
Ready mixed concre
Concrete blocks
Stucco materials, bri

Rinker Materials Co Plant
Mail: 8165 Rinker W
Fl 32819-5599
J. David Bordenkirch
Bob Anderson
PH (407) 876-2950
Emp: 38
Ready mixed concre
Concrete blocks

Robbins Manufactu
Mail: 7205 Rose Av
Fl 32810-341
Roy Sell, Branch Mg
PH (407) 293-0321
Emp: 10
Wolmanized yellow
Wolmanized poles
Dri con fire retarden

Robertson Optical L
Mail: 3210 Corrine
Fl 32803-22
William Parker, Vice
PH (407) 894-0551
Emp: 25
Optical lenses

Advanced Welding & Mfg. Inc.
Mail: 10 W. Illiana St Orlando
Fl 32806-4408
John Berndobler, President
Gloria J. Berndobler, Sec./Treas
PH (407) 849-6387
Fax (407) 649-4149
Emp: 6
Laser frame production 3699

Aerospace Defense Coatings,Inc
601 N. Orange Blossom Trail Orlando
Mail. P. O. Box 2609
Fl 32802-2609
Thomas W. Scott, President
Gary Hall, Vice Pres
PH (407) 843-1140
Emp: 3
Mil-spec painting 3999
Aerospace 3769

Agri-Machinery, Inc.
Mail: 3489 All American Blvd. Orlando
Fl 32810-4788
J. R. Turner
Thomas Billings
PH (407) 299-1592 Import & Export
Emp. 30
Custom machinery 3523
Conveyors 3523
Agricultural machinery 3523

Air-Flite Containers, Inc.
Mail: 2699 Forsyth Rd Orlando
Fl 32807-6497
Kevin E McDonald
E P. McDonald
PH (407) 678-3928 Export
Emp: 15
Wood boxes 3449
Corrugated boxes 2653

Air Products And Chemicals, Inc.
Mail. 1115 Sligh Blvd Orlando
Fl 32806-1030
Donald C. Mayer, Branch Mgr
PH (407) 648-1662
Emp. 12
Indus/specialty/med gases equipment 3823

Airfoil Textron, Inc.
2287 Premier Row Orlando
Mail. P. O. Box 590588
Fl 32859-0588
George A. Mason
Janet Rivera
J. Andrew Noyes
PH (407) 859-0632
Fax (407) 859-3493
Emp: 294
Precision jet engine parts 3728
Titanium compressor blades for jets 3728

Airtron, Inc.
Mail: 4201 34th Street Orlando
Fl 32811-5696
Mike Kramer
Gordon Rhen
Bill Arlinghouse
PH (407) 425-8672
Emp. 30
Air conditioning 3585
Heat pumps 3585
Heating 3585

Al-Len Lock Co.
Mail: 4550 W Colonial Dr. Orlando
Fl 32808-8195
Allan Pritzker, President
Sharon Pritzker
PH (407) 293-0057 Import & Export
Emp. 6
Custom res hardware & acces. 3261
Sales 3499
Contract hardware 3421

Alcan Building Products
Mail: 1730 N. Forsyth Rd Orlando
Fl 32807-5274
John Cugura, Dist Mgr.
PH (407) 671-1527
Emp: 10
Windows & doors 3442
Aluminum siding & facia 3444
Vinyl siding 3292

All Metal Fabricators, Inc.
Mail 19 N. Texas Ave. Orlando
Fl 32805-2162
Ervin K. Regal, President
Sue Regal
PH (407) 293-6337
Emp. 21
Stainless steel fabrication 3312
Commercial kitchens 2514
Restaurant equipment 3556

All State Pallets
Mail: 153 W. Landstreet Rd. Orlando
Fl 32824-7820
Darrell Rogers, Gen Mgr
PH (407) 885-8087
Emp. 6
Rebuilt pallets 2448

Allied Septic Tank Co Inc
Mail. 5640 Carder Rd Orlando
Fl 32810-4785
William P. Thomas, President
PH (305) 293-8510
Emp: 40
Concrete products & septic tanks 3272

Alpha Draperies, Inc.
Mail: 627 Virginia Dr. Orlando
Fl 32803-1857
Frank Guy, President
PH (407) 898-5861
Emp. 6
Draperies 2391
Verticals 2591
Mini blinds 2591

Alpha Manufacturing, Inc.
19 North Texas Ave Orlando
Mail: 15 N. Texas Ave.
Fl 32805-2162
Ervin K. Regal, President
PH (407) 293-6337 Export
Fax: (407) 295-6860
Emp: 15
Commercial kitchens 3556
Ventilation systems 3444
Restaurant equipment 3556
Sheet metal products 3444

Aluma Kraft Awning
Mail. 1310 W. Central Blvd. Orlando
Fl 32805-1708
James W Wingo, Owner
PH (407) 422-6139 Export
Emp. 21
Screen rooms,cabana rooms,pool enc. 3442
Awnings, patio covers, siding & sof 3444
Other aluminum products 3441

American Anchor Corp
Mail: 4111 34th Street Orlando
Fl 32811-6472
William Stahl, Pres
Carla McCowen, Sls Mgr
PH (407) 843-1661
Fax (407) 841-4237
Toll-Free 1-800-321-4445
Emp: 30
Expansion/masonry/concrete anchors 3429

American Blueprinting & Supplies Inc
Mail: 1999 W Fairbanks Ave.
Fl 32789-4586 Winter Park
Robert D. Smith, President
Jim Croft, Gen Mgr
PH (407) 644-5366
Fax. (407) 644-7456
Toll-Free. 1-800-432-0856
Emp: 28
Blueprint processing/offset print 2759
Plotter service 3577
Copying 2759

American Colors
Mail: 685 Rocket Blvd. Orlando
Fl 32824-8556
Lewis A. Wible Jr, Dir/Mktg
PH (407) 851-3030 Export
Emp: 17
Gel coats for boating industry 3089
Shower stalls 3089
Colors & pigments 2816

American Crime Prevention Corp.
Mail: 2467 John Young Pkway Orlando
Fl 32804
Bart Waymira, President
PH (407) 295-4777
Emp: 5
Burglar alarms 3663

American Machinery Corp.
2730 Eunice Avenue Orlando
Mail: P. O. Box 3228
Fl 32802-3228
Fred Kelly, President
Thomas A. Gnesda, Exec VP
PH (407) 295-2581 Export
Fax: (407) 290-5203
Emp: 50
Food processing machinery 3556
Post harvest chemicals 2833

American Products
Mail: 10208 General Dr. Orlando
Fl 32824-8521
H. Wesley Lear
Dick Moore
Vickie Saylor
PH (407) 859-1322 Export
Fax: (407) 859-7622
Toll-Free 1-800-223-1795
Emp: 20
Swimming pool & spa equipment 3949

American Systems Products Inc.
Mail: 215 Candace Dr. Maitland
Fl 32751-3359
PH (407) 774-4074
Emp: 9
Semiconductor & related devices 3674

American Testing Laboratories TEC, Troy, Mich
Mail: 1650 Acme St. Orlando
Fl 32805-3670
P Ralph Brown
PH (407) 843-1310
Toll-Free: 1-800-940-1310
Emp: 25
Commercial testing labs 8734

Analysis And Technology, Inc.
Mail: 3670 Maguire Blvd. Suite 102
Fl 32803-3720 Orlando
Susan Varnadoe
PH (407) 894-4767
Fax: (407) 894-4878
Emp: 7
Ineractive courseware development 7371
Video production for training 7812

Anderson Furniture Mfg.
Mail: 4690 Old Winter Garden Rd.
Fl 32811-1799 Orlando
Harold A. Anderson, President
Helen Marie Anderson, Vice Pres.
PH (407) 293-6797
Emp: 3
Wood household furniture 2511
Upholstered sofas & chairs 2512
Mattress & box springs 2515

Anderson's Can Line Fabrica Equipment Co.
Stillwater Ave & SR 437
Mail: P.O. Box 116
Ocoee, Fl 34761-0116
Jon V. Anderson
James R. Cascarelli
PH (407) 889-4665
Emp: 15
Can line equipment & conveyin
Fabrication

Andrea Quality Cheesecake
Mail. 6020 Edgewater Dr.
Fl 32810-4801
Angelo Manfrede, Owner
Tosca Manfrede, Co-Owner
Andrea Whitehouse
PH (407) 291-2490
Emp. 4
Varieties of cheesecake
Baked wedding cheesecakes
Deli items

Ani Arts Studio
Mail 6109 Hialeah St
Fl 32808-6066
PH (407) 299-0090
Emp 5
(computer systems consult/ani ing)
(data processing services)
(computers - software & servic

Anthony Custom Controls, I.
Mail. 6888 Silver Star Rd
Fl 32818-3123
William Anthony, Vice Presiden
PH (407) 295-0486
Emp: 4
(control manufacturers industri

Application Systems Interna
500 Winderley Pl, Suite 111
Mail: P. O. Box 948076
Fl 32794-8076
Robert L. Naugle, President
S. G. Crocker
PH (407) 875-1112
Fax (407) 845-1063
Toll-Free: 1-800-255-2581
Emp: 10
Batch svcs; IBM mid-rnge hrdv.
data procsng svcs
On-line time sharing services
Fixed assets mngmt. software
Consulting - DP services

Applied Combustion Techno
Mail 2050 S Orange Blossom
Fl 32703-7759
Michael Varney
PH (407) 889-7337 Ex
Fax: (407) 889-2228
Emp: 5
Explosives design & testing
Product liability analysis

Applied Computer Techniqu
Mail: 3914 Dekalb Dr
Fl 32809-1424
Lenard J. Persin
Tim Lanier
PH (407) 851-2525
Emp: 5
Research & development-elect
Micro computer based product design
CAM/CAD services / PCB layo. etc

Applied Technology Assoc.
Mail. P.O. Box 149434
Fl 32814-9434
Robert Cavallen
PH (407) 894-6151
Emp. 0
Aerospace res. & devel.

s, Inc.
Orange Ave — Orlando
O Box 7725
2854
Robinson Jr, President
rch
) 898-2808 — Export
7) 898-1674
1-800-248-2808
28
nal & print marketing for leisure — 2759
beverage and ment industries — 2099

rs Press, Inc.
24 Forsyth Rd. — Orlando
32807-5292
) Cowart, President
e Cowart, Secretary
) 677-5533
37
nt., design, lithography — 2752

ledical Corp
06 L B McLeod Rd Ste F
32811-5664 — Orlando
P Kennedy
P. Griggs
) 841-2115
150
equipment supplies — 3841
ealth services — 3841

own Bottlers Of Chicago Division
01 L B. McLeod Rd. — Orlando
32805-6698
ng, Vice Pres.
) 841-3211 — Export
146
soft drinks — 2086

aft Inc
ndstreet Rd. — Orlando
O box 593848
32859-3484
Begley, President
G. Begley, Vice Pres
) 851-0309
7) 240-4854
1-800-829-7231
50
molded rubber products, ts, bumpers — 2653

Professional Service
366 Central Florida Pkwy — Orlando
32821-8772
7) 239-0311
5
ter software svcs) — 7372

Voodbury, Inc.
150 A Edgewater Drive — Orlando
32810
Dobbs Jr.
ompson, Asst Mgr
7) 291-4114
07) 292-9627
2
emical supplies(pest control, rse) — 2879

465 Parkway Center Court
32808-1047 — Orlando
Enthal, President
Enthal
7) 295-5023
4
ercial printing — 2752
tting — 2791
design — 2759

SE, Inc.
Mail: 11236 Satellite Blvd. — Orlando
Fl 32821-9222
Edward Strong, President
Edna Ayers, Off Mgr
Gerald Kopp, Pur Agent
PH (407) 859-9317 — Import & Export
Fax: (407) 850-6978
Toll-Free: 1-800-344-6319
Emp: 45
Parachute asm & related components — 2399

Charles E. Sackett Machine Shop, Inc.
5500 Old Winter Garden Rd — Orlando
Mail: P. O. Box 616580
Fl 32861-6580
Charles E. Sackett
PH (407) 298-5540
Emp: 17
General repair shop — 3599

Sardee Of Florida
Sardee Industries
Mail: 2211 W Washington St. — Orlando
Fl 32805-1295
S. Sarovich, President
B. R. Juskie, Vice Pres.
PH (407) 295-2114 — Export
Emp: 23
Depalletizers — 3569
Palletizers — 3569
Conveyors — 3535

Sawtek, Inc.
1818 S Hwy 441 — Apopka
Mail: P. O. Box 605901
Orlando, Fl 32860
Steven P. Miller, President
PH (407) 886-8860 — Import & Export
Fax: (407) 886-7061
Emp: 122
Micro electronics components — 3674
R & D on electronics — 8711
Surface accoustical wave filters — 3679

Schau Associates
Mail: 6912 Sugarbush Dr — Orlando
Fl 32819-4515
PH (407) 352-1716
Emp: 5
Research & development labs — 8734

Schwartz Electro-Optics, Inc.
Mail: 3404 N. Orange Blossom Trail
Fl 32804-3498 — Orlando
William Schwartz, President
Tim Geltz, Mktg Mgr
Zelma Slusser
PH (407) 298-1802 — Export
Fax: (407) 297-1794
Emp: 110
9eapon simulator systems — 3369
Solid state & turntable lasers — 3699
Laser rangefinders — 3699

Science Applications International Corporation (SAIC)
Mail. 3045 Technology Pkwy — Orlando
Fl 32826-3299
Beverly Kitaoka, Oper Mgr
Charley Binney Division Mgr
PH (407) 282-6700
Emp: 75
Computer related services/training programs — 7379
Computer software/artificial intelligence — 7379

A. C. Scott Construction & Paving
Mail: 2730 Forsyth Rd. — Winter Park
Fl 32792-6672
A. C. Scott, Owner
PH (407) 671-6721
Emp: 12
Asphalt paving — 2951

O. M. Scott & Son
1151 E Oak Street — Apopka
Mail: P. O. Box 2187
Fl 32704-2187
Wayne Mixson
PH (407) 889-4200
Fax: (407) 889-2201
Emp: 5
Research lab — 8734

Sealy Mattress Company
11220 Space Blvd. — Orlando
Mail: P. O. Box 590049
Fl 32859-0049
Lou Sammartano, Plt Mgr
Gordon Jones
PH (407) 855-8523 — Export
Emp: 135
Mattress & box springs — 2515

Seglo Paints Manufacturing Company
70 East 4th Street — Taft
Mail: P. O. Box 621296
Orlando, Fl 32862-1296
Bill Macias
PH (407) 855-4064
Emp: 4
All type of paints — 3952
Industrial coatings — 2851

Senninger Irrigation, Inc.
Mail: 6416 Old Winter Garden Rd.
Fl 32811-1399 — Orlando
Andy Healy, Pres
PH (407) 293-5555 — Export
Emp: 65
Agric. sprinklers — 3494
Pressure regulators — 3494
Threaded pipe fittings — 3494

Sentinel Color Graphics
Mail: 633 Orange Ave. N. — Orlando
Fl 32801
Bill Ireland, Camera Mgr
PH (407) 420-5622
Emp: 34
Color separation, typographical wk — 2791

Sentinel Communications Company
Tribune Company, Chicago
633 N Orange Avenue — Orlando
Mail. P. O. Box 2833
Fl 32802-2833
Harold R. Lifvendahl, Pres./Pub.
William Steiger, VP/Dir of Adv
Geraldine C. Davis, VP/Dir Hum Res
PH (407) 420-5000
Fax: (407) 420-5661
Emp: 1,553
Newspaper publishing & printing — 2711
Daily newspaper — 2759
Commercial printing — 2752

Sewell Plastics, Inc.
Mail: P. O. Box 593452 — Orlando
Fl 32859-3452
Bob Lappi, Reg Opr Mgr
Steve Groves, Opr Mgr
PH (407) 855-2721 — Export
Emp: 198
Plastic containers — 3089

Shaver Associates Inc
Mail: 717 N Magnolia Ave — Orlando
Fl 32803
C.A. Shaver, President
PH (407) 423-1213
Emp: 6
Computer software — 7372

Ship Analytics, Inc.
Mail: 1177 Louisianna Ave., Suite 208
Fl 32789-2352 — Winter Park
Jim Duva
PH (407) 644-6821
Emp: 9
Business consulting services — 8748
Interactive courseware — 7372

Shirt Farm
2410 Coolidge Avenue — Orlando
Mail: P. O Box 2338
Winter Park, Fl 32790-2338
Graham Jackson, President
PH (407) 629-1040
Emp: 12
Printed t-shirts — 2752
Printed sportswear — 2752

Siegfried, Inc/dba PDQ Instant Print
Mail: 2600 E. Robinson St. — Orlando
Fl 32803-5824
Jean E. Siegfried, President
Steven C. Siegfried, Vice Pres
PH (407) 894-2521
Fax: (407) 895-5028
Emp: 10
Commercial printing — 2759
Copying & duplicating — 3541

Silicon Graphics, Inc.
Mail: 900 Winderley Place, Suite 130
Fl 32751-7229 — Maitland
Russell patten, Brch Mgr
PH (407) 660-0073
Fax: (407) 660-8981
Emp: 11
Computer graphic workstations — 8711

Silver Springs Citrus Cooperative
Mail: P. O. Box 771046 — Winter Garden
Fl 34777-1046
Duke Crittenden, President
Bill Youngblood, Exec VP
Phil Tope, Vice Pres
PH (407) 656-1122 — Import & Export
Emp: 150
Frozen orange juice concentrate — 2037
Single strength juice — 2037
Citrus by products — 2048

Simcom Systems Inc
427 Primrose Drive — Orlando
Mail: P. O. Box 19284
Fl 32814-9284
Bruce H. Campbell, President
Bill Maxey, Train Dir
PH (305) 896-8799
Emp: 20
Electronic computing equipment — 3571
Computer related services — 7379

Sinco Engineering Co
Mail: 4317 Bradley Ave. — Orlando
Fl 32809-1417
PH (407) 855-8702
Emp: 9
Radio & tv communication equip — 3663

Small Business Computer Software
Mail: 1236 E Colonial Drive — Orlando
Fl 32803-4702
Theodore Owens, Owner
PH (407) 422-7855
Emp: 6
Computer software — 7372

Smyth Lumber Company Roof Truss Division
Mail: P. O. Box 7399 — Orlando
Fl 32854
Donald J. Smyth, President
James R.Smyth, Secy/Treas
PH (407) 299-1522
Emp: 20
Roof trusses — 2439
Floor trusses — 2439
Structural wood beams — 2439

Software Design Group, Inc. (SDG)
Science Applcatns Int'l Corp (SAIC)
Mail: 450 N Lakemont Avenue
Fl 32792-3102 — Winter Park
PH (407) 657-1300
Fax: (407) 657-9823
Emp: 27
Computer software applications — 7371

ECC International Corp.
5882 S. Tampa Avenue Orlando
Mail: P. O. Box 598022
Fl 32859-8022
George Frye Jr, Exec VP
PH (407) 859-7410 Export
Fax: (407) 851-1871
Emp: 750
Simulation training equipment 3669

EER Systems Research Park
Mail: 3290 Progress Dr., Suite 165
Fl 32826-3279 Orlando
PH (407) 281-1935
Emp: 0
Space research and technology 9661

EMS Development Corp.
Mail: P.O. Box 140313 Orlando
Fl 32814-0313
A. Kunen
PH (407) 647-1807 Export
Emp. 120
Training simulators 8731

Earth Station Services
Mail: 2323 Marden Road Apopka
Fl 32703-6928
Charles Raila
PH (407) 889-4550
Emp: 0
Space research and technology 9661

Eatonville Diversified, Inc
Mail: P. O. Box 2185 Eatonville
Fl 32751-1999
Nathaniel Vereen, President
Mark Vereen, Sr. V.P.
PH (407) 628-2109 Import & Export
Emp: 4
Cabinets 2541
All types woodwork 2431
Flooring 2426

Electrasol Laboratories Inc.
Mail: 2326 Felding Wood Rd Maitland
Fl 32751-3659
Harold Dessau, President
PH (407) 831-4181
Emp: 2
R & D, simulation and testing labs 8731

Electric Specialty, Inc.
Mail: 1240 W. Landstreet Rd. Orlando
Fl 32824-8029
Larry B. Morris
PH (407) 855-9486 Export
Fax: (407) 851-3514
Emp: 33
Process control panels 3625
Heat pump, ground source 3585
Pump control systems 3561
Power systems 3621

Electro Chromium Company
Mail: 549 N. Orange Blossom Trail
Fl 32805-1437 Orlando
Arthur Martineau, President
Ruby Martineau, Vice Pres/Sec
Glenn Martineau, Vice Pres
PH (407) 425-2217
Emp: 5
Industrial hard chrome plating 3471
Polishing 3541

Electro Optics Inc
Mail: 3535 Forsyth Rd Winter Park
Fl 32792-7422
PH (407) 678-2767
Emp: 10
Optical instrument & lens manufacturer 3827

Electronic Security, Inc.
Mail: 1331 W. Central Blvd. Orlando
Fl 32805-1794
Troy M. Deal, President
Brian Vancata, V.P. Mktg.
PH (407) 849-6426 Export
Emp: 15
Complete security systems 3669

Emulex Corp
Mail: 1093 S Semoran Blvd Winter Park
Fl 32792-5502
PH (407) 679-2550
Emp: 10
Computing equipment electronics 3571

Encore Computer Corp.
Mail: 3165 McCrory Place, Suite 135
Fl 32803-3727 Orlando
Robert Kollar
PH (407) 898-2741
Fax: (407) 894-8973
Toll-Free: 1-800-432-1825
Emp: 7
Computer related services not elsewhere found 7379

Engineering Technology, Inc.
Mail: 3275 Progress Dr Orlando
Fl 32826-3230
Paul Morgan, President
Denise Daniels
PH (407) 281-1948
Fax: (407) 275-1630
Emp: 20
Design of mechanical mechanisms 8742
3572Fluid mechanical test devices 8711
Computer analysis 3577
Testing services 3825

Erie Crate & Mfg Co
Mail: 780 Central Florida Pkwy. Orlando
Fl 32824-8557
Virginia VanGeem, Pres
Jim Golembeski, VP/ Plt Mgr
PH (407) 855-5934 Export
Toll-Free: 1-800-426-8981
Emp: 35
Plastic crates 3089

Executive Press, Inc.
Mail: P. O. Box 555007 Orlando
Fl 32855-5007
D. R. Brownlee
PH (407) 422-3024
Emp: 40
Commercial printing 2759

Expert Applications, Inc.
Mail: 2438 Wekiva Ridge Rd Apopka
Fl 32712-4043
Ernie Anderson
PH (407) 889-4318
Emp: 2
Expert systems 8742
Computer graphics 7379
Training & simulation 8734
Marketing & proposal consultants 7371

Extrufix, Inc.
Mail: 4542 L. B. McLeod Rd, Unit E
Fl 32811-5667 Orlando
Frank McNerney, President
PH (407) 648-0755
Emp: 4
Injection molding 3089

FLM Building Products, Inc.
850 S Hughey Ave Orlando
Mail: P. O. Box 5683
Fl 32855
Mike Edwards, President
PH (407) 843-6600 Import & Export
Emp: 95
Wilson art 2675
Plywood and particle board 2435
Lumber 2421

FMC Airline Equipment Division
FMC Corporation
Mail: 7300 Presidents Dr. Orlando
Fl 32809-5696
Jerry Sibley
Tim Roberts
Arthur Belinger
PH (407) 851-3377 Import & Export
Emp: 350
Air cargo loading equipment 3731
Airline ground support equipment 3669

Falkner Inc.
1621 Alden Rd. Orlando
Mail: P. O. Box 673
Fl 32802-0673
James H. Falkner, President
PH (407) 898-2541
Emp: 11
Sheet metal spec. - architectural 3444
Ventilation 3634

Farco Plastics Supply, Inc.
Mail: 1012 Sligh Blvd. Orlando
Fl 32806-1029
PH (407) 422-6644 Import & Export
Fax: (407) 422-7387
Toll-Free: 1-800-243-2726
Emp: 6
Plastics supply centers; sheet's rod's tube, film 3081
Silicone sealants, caulking 2869

Fasco
Mail: 2141 W Central Blvd Orlando
Fl 32805-2166
I.R. Amenne, Chairman
PH (407) 291-2556
Emp: 0
Semiconductors 3674

Faulkner Plastics, Inc.
Cadillac Plastic & Chemical Co.
Mail: 480 W. 27th Street Orlando
Fl 32806-4487
Barry Burczyk, Branch Mgr.
PH (407) 422-5136 Import & Export
Toll-Free: 1-800-444-5136
Emp: 9
Plastics: Sheet, Rod, Tube & Film 3081
Plastic Fabrication & Design 3089
Skylights, Vac. Forming 3211
Polycarbonate, Acrylic & Nylon 2821

Fay Tool And Die, Inc.
Mail: 5925 Precision Dr. Orlando
Fl 32819-8396
Douglas N. Fay, President
Gene Bressler
PH (407) 351-1812
Emp: 50
Precision/CNC machining 3599
Die making jigs & fixtures 3544
Machining of aircraft parts 3728

Ferguson & Ferguson Sys. Corp.
Mail: 1314 W. Anderson St. Orlando
Fl 32805-2402
C. R. Ferguson, Pres/Gen Mgr
PH (407) 422-2362
Emp: 10
Television satellites 3661

Fiber Optic Cable Corp.
Mail: 1666 Providence Ct. Orlando
Fl 32818-5624
M A Achareka
Emp: 0
Photonics and fiber optics 3829

Fidelity Press, Inc.
Mail: 649 Triumph Court Orlando
Fl 32805-1281
Joe Trivelli, Owner
PH (407) 297-8484
Fax: (407) 298-5063
Emp: 30
Commercial & lithographic printing 2752

Finfrock Industries, Inc.
Mail: P. O. Box 607754 Orlando
Fl 32860-7754
Robert D. Finfrock Jr, Pres
Jerry D. Sellers, VP/Sls
PH (407) 293-4320 Import
Fax: (407) 297-0512
Emp. 54
Prestressed concrete products 3272

Fire Out Systems, Inc.
Mail: 412 Piedmont
Fl 32806-1021
Russell Dupree, President
PH (407) 422-7767
Emp: 10
Stainless/galv steel range hoo

Fish Finder Industries
Mail: 1233 W. Jackson St.
Fl 32805-2270
Harold F. Hall, President
Ted Ensminger, Vice Pres
Al Bailey, Comp
PH (305) 425-0045
Emp: 16
Photoscreening

Flav-O-Rich
Mail: P. O. Box 5487
Fl 32805
Elmer Goins, Plant Mgr
PH (407) 843-5060
Emp: 15
Milk
Ice cream
Dairy products

Florida Administrators Inc.
Mail: P.O. Box 20173
Fl 32803
Roy Morgan
PH (407) 894-5171
Emp: 7
Computer related services ne

Florida Brace Corporation
Mail: P. O. Box 1299
Fl 32790-1299
Ben B. Moss, Pres/Owner
PH (407) 644-2650 E
Emp: 17
Spinal braces & collars

The Florida Catholic
321 Hillman Avenue
Mail: P. O. Box 3551
Fl 32802-3551
Fr. David P. Page
Henry P. Libersat, Jr.
PH (407) 423-3438
Emp: 16
Newspaper publishing

Florida Coca-Cola Bottling
Canned Products Div.
Mail: 2900 Mercy Dr
Fl 32808-3810
Jack E. Thomas, Manager
PH (407) 295-9290
Emp: 52
Canned soft drinks

Fla. Generator, Inc.
Mail: 6200 E. Colonial Dr.
Fl 32807-3647
Dan Chisholm
Ron Smith
PH (407) 277-5200 I.
Emp: 18
Alternators & starters

Florida Informanagement
P.O. Box 1547
Mail: Po. Box 1547
Fl 32802-1547
W. Harry Shuman, President
PH (407) 841-1712
Emp: 213
Data proc mng

Florida Metal-Craft Inc.
47 S. Dillard Street
Mail: P. O. Box 771196
Fl 34777-1196
R. L. Burnett, President
T. T. Burnett, Vice Pres.
PH (407) 656-1100
Fax. (407) 656-6970
Emp. 14
Machine & sheet metal sh
Shear, brake & roll

Kraft, Inc./Dairy Group
Kraft, Inc.
Mail: 1945 Traylor Blvd. Orlando
Fl 32804-4713
Mack Pleieones
PH (407) 422-9873
Emp: 16
Ice cream 2024
Cultured dairy products 2023

Jim Kragh & Associates, Inc.
Mail. 218 Jackson Street Maitland
Fl 32751-5570
James Kragh, President
PH (407) 629-0304
Fax (904) 222-5520
Emp 23
Mechanical, electrical & plumbing design 3585

La Flor De Mexico Inc
Mail 270 W. Plant St Winter Garden
Fl 34787-3012
Rene Serrano, President
Edwin Serrano, Vice Pres
Gerardo Serrano, Vice Pres
PH (305) 656-4317
Emp 36
Tortillas/taco shells/mexican pastr 2099

La Providencia Bakery, Inc.
Mail: 270 W Plant Street Winter Garden
Fl 34787-3012
Rudolph Ortega, President
Lucy Ortega, Sec/Treas
PH (407) 656-4317
Emp: 13
Mexican breads 2051

LaBerge Printers, Inc.
Mail 1328 W. Church St. Orlando
Fl 32805-2493
Richard LaBerge
Larry Cowart
PH (407) 896-4551
Fax: (407) 425-6291
Emp 26
Printing 2759

Lambert Corporation Of Florida
Mail 20 N. Coburn Ave. Orlando
Fl 32805-2198
Roger D. Meyer, President
PH (407) 841-2940 Import & Export
Fax: (407) 839-1890
Toll-Free: 1-800-432-4746
Emp. 12
Spec. paints for construction 2851
Spec. construction chemicals 2819

Lamp Plants & Such, Inc.
Mail. P O Box 992 Apopka
Fl 32704-0992
C. Bartlett
Wendell Bartlett
PH (407) 886-8419 Export
Emp: 3
Touch sensitive lamps with plants 3645

Lanman Lithotech, Inc.
Mail: 21 N. Texas Ave. Orlando
Fl 32805-2162
T. Halter Cunningham, President
Dever S. Pedley, V.P./Secy
PH (407) 293-3980
Emp: 32
Color separations 2796

Laser Applications, Inc./div Lasermetrics Inc.
Mail: 12722 Research Pkwy Orlando
Fl 32826-3227
Robert Goldstein, President
Joseph Saig, Exec VP
PH (407) 380-3200 Import & Export
Fax (407) 381-9019
Emp. 45
Industrial lasers 3669
Scientific lasers 3812

Laser Ionics, Inc.
Trimedyne, Inc.
Mail: 701 S. Kirkman Rd. Orlando
Fl 32811-2090
William J. Newell, Exec VP/Gen Mgr
Drew Nelson, Sls Mgr
Helen L. Talbert, Exec Sec/Pers
PH (407) 298-1561 Export
Fax: (407) 297-4167
Toll-Free: 1-800-822-1561
Emp: 19
Argon/ion gas lasers 3829
Krypton ion gas lasers 3829
Photodynamic therapy laser systems 3829
Neon lasers 3829

Laser Photonics, Inc.
Mail. 12351 Research Parkway Orlando
Fl 32826-3297
Mark Fukuhara
Patty Roesner
PH (407) 281-4103 Export
Emp: 80
Lasers for medical uses 3845
Lasers for scientific uses 3845
Lasers for industrial applications 3845

Lawton Printers, Inc.
Mail: 2000 Silver Star Rd. Orlando
Fl 32804-3357
Ces Lawton, President
Jeff Heslep, Gen Mgr
PH (407) 293-8131
Fax: (407) 290-6570
Emp 14
Offset printing 2752
Letterpress printing 2759

Lazerdata Corporation
Mail: 2400 Diversified Way Orlando
Fl 32804-4707
Michael G. Reid
PH (407) 843-8975
Emp. 44
Laser bar code readers 3823

Lebruno
Mail. 10901 Rhema Rd. Orlando
Fl 32821-9275
Dr. Mark D. Mosher, President
Mr. Jeff L. Recker, Exec. V P.
PH (407) 855-1290
Emp: 51
Alum. products for homes/ mobl.homes 3479
Awning and screen enclosures 3444
Pvc windows 3999

Lee Contact Lense Lab Inc
Mail: 214 E Marks St Orlando
Fl 32803-3819
PH (407) 841-6227
Emp: 8
(ophthalmic goods manufacturers) 3851

Lee Laser, Inc.
Mail: 3718 Vineland Road Orlando
Fl 32811-6438
Chong Lee, President
Robert L. A. Schncker
PH (407) 422-2476 Export
Fax. (407) 839-0294
Emp: 20
Lasers 3911
Radio & tv communication equipment 3663

T. G. Lee Foods, Inc.
Mail: P. O Box 3033 Orlando
Fl 32802-3033
Darryl R. Mahan, V P./Treas
PH (407) 894-4941
Emp: 350
Dairy products & milk 2026

Lewnetco, Inc./dba Pickett Printing
Mail: 6210 All American Blvd. Orlando
Fl 32810-4739
Lewis D Paroline, President
PH (407) 298-1380
Fax: (407) 292-9063
Emp. 10
Offset printing 2752
Letterpress printing 2759

Lindberg Heat Treating Co.
Mail: 316 S. Hughey St. Orlando
Fl 32802
Leo Thompson, President
N. Thomas Held, Div Mgr
PH (407) 843-7145
Emp. 40
Heat treat ferrous/nonferrous metal 3312

Linear Machine Company
Mail: 7024 S. Orange Ave. Orlando
Fl 32809-6096
Donald N. Emanuel, President
PH (407) 851-4680
Emp: 8
Metalworking machinery 3549
Tools & dies 3544

Link Development Corp
Mail: 7617 Narcoossee Rd. Orlando
Fl 32822-5541
Robert Simpson, President
Harris Springer, Plant Mgr
PH (407) 277-4300 Import & Export
Fax: (407) 282-6895
Toll-Free 1-800-367-4030
Emp: 15
Golf clubs 3949

Liquid Air Corporation
Mail: 3010 Eunice Ave Orlando
Fl 32808-3199
Randy Welter
PH (407) 293-7951
Emp: 9
Oxygen, nitrogen, argon 2813

Liquid Carbonic
Mail: 403 Zell Dr. Orlando
Fl 32824-7633
Jay Legeai, Dist.Mgr.
PH (407) 851-4711
Emp: 7
Industrial & specialty gases 2813

Lite Steel Fabricators, Inc
Mail. 11929 S Orange Blossom Trail
Fl 32821-9252 Orlando
John Pawlack Jr, Chrm/Pres
William Gillooly, Vice Pres
Gevelle Pawlack, Sec/Treas
PH (407) 859-7004
Fax: (407) 857-8647
Emp: 28
Strtl steel/metal stairs/handrails 3441

Litho Prepsters, Inc.
Mail: 711 W. Colonial Dr. Orlando
Fl 32804-7309
Don M DeBorc, President
PH (407) 841-1211
Fax: (407) 839-0865
Emp: 12
Lithographic laser color separations 2752
Lithographic stripping 2752
Composed film neg or pos 2752
Proofing cromalins, match prints & color keys 2752

Litton Laser Systems
Mail: P. O. Box 7300 Orlando
Fl 32854
M.R Yeager, President
PH (407) 295-4010
Emp. 481
Laser systems 3826

Litton Systems Inc
Mail 2787 S Orange
Fl 32703-4397
PH (407) 297-4785
Emp: 250
Engineering & scienti instruments

Lofar Corporation
Mail: 101 E. Copelan
Fl 32856-0325
E. L. Farrar Jr
PH (407) 423-4499
Emp: 0
Medical software
Distributor medical h software
Homehealth agency s

Lombardi's Seafood
Mail: 7491 Brokerage
Fl 32809-5633
Anthony Lomdardi
PH (407) 859-1015
Emp. 100
Fresh and frozen sea

Lott's Concrete Proc
429 N Hennis Rd
Mail: P O. Box 7712
Fl 34777-1255
Johnnie P Lott, Pres
Jerry Lott, Vice Pres.
PH (407) 656-2112
Emp: 41
Concrete lintels and s

Ludlum Associates (
1915 E Colonial Dr,
Mail. P. O. Box 5362
Fl 32853-6274
Mike C. Jenkins
Gerald Rehbein
PH (407) 894-7761
Fax (407) 898-561
Toll-Free. 1-800-525
Emp: 4
Industrial controls
Aircraft parts & auxil

M & N Door & Trim
Mail: P. O. Box 7948
Fl 32804
Ron C. Hardy, Exec.
PH (407) 298-5600
Emp: 21
Prehung doors
Commercial hollow m frame

M & W Printers
Mail: P. O. Box 564
Fl 32790-0564
Tommie Manuel
PH (407) 645-3536
Emp: 3
Commercial printing

MP Manufacturing &
Mail: 2116 W. Centr
Fl 32805-2131
Michael Padula Jr. O
PH (407) 841-2653
Emp: 15
Cnc milling
Cnc lathe
Conventional mill

MVAK Technologie
Mail: 7101 President
Fl 32809
Frank Giacona, Vice P
Paul McVey, Sales M
PH (407) 438-5700
Fax: (407) 438-057
Toll-Free 1-800-282
Emp: 12
Vacuum pump rebuil
Vacuum pumping flu
Vacuum pumps new
Filters, fluid, oil

ngraving Inc
Michigan Orlando
6-4416
and, President
3-3239
hoto-engraving - 2796

mith Blueprinters, Inc
Division Ave. Orlando
5-4794
ith, President
1-5944
5
2759

c.
rkway Center Court
3-1040 Orlando

1-6500
8-0429
evelopment labs 8731

c South, Inc.
esidents Drive Orlando
1
eley, President
-6400
1-1045
1
ns 2796

oration
Bay St Winter Garden
-2699
President
e Pres.
-4494 Import & Export
ated cassettes 3577
3577
records 2782

e, Inc
Orange Ave. Orlando
-6955
President
eder, Secy-Treas
Office Mgr
2552
e tubs, vanity tops 3281

etics
odcock Rd. Orlando
4899
ting services 8748

e Ellenor Dr Orlando
4645
ident
0540
tion 3669

es, Inc
ehurst Dr. Orlando
8343
s, President
, Sec/Treas
3066
8262
3732
3732
3732

Marketing Connection/Florida
Mail: 7616 Sothlnd Blvd, Ste 100
Fl 32809-8500 Orlando
Leon L. Lebeau
PH (407) 855-4321
Fax: (407) 855-4616
Emp: 15
Computer graphics 7372
Business meetings 8748
Video production 7812

The Markham Company, Inc.
Mail: 1184 Alden Rd. Orlando
Fl 32803-2566
G P. Markham, Pres/Treas
Jessie C. Markham
Nellie F. Rodgers, Vice Pres
PH (407) 898-8981 Import & Export
Fax: (407) 896-3090
Emp: 32
Military canvas items 2394
Awnings 2394
Tarpaulins 2394

Martin Marietta Electronics & Missiles Group
Sand Lake Road Orlando
Mail: P. O. Box 5837
Fl 32855
Allan M. Norton, Pres
Gerald R. Langheim, PR Dir
Donald T. Byrme, Vice Pres
PH (407) 356-2000
Emp: 11,200
Precision guided munitions 3829
Avionics 3679
R & D 3769

Martin Marietta Information Systems Group
Martin Marietta Corporation
6021 Rio Grande Orlando
Mail P.O. Box 590385
Fl 32859-0385
Jack Cline
Robert Creech
Debra Henry
PH (407) 826-7000
Toll-Free: 1-800-237-4575
Emp: 1,058
Data processing services 7374
Computing equipment electronic 3577
(computer systems consult/ants/ing) 7371

Maruka Machinery Corp. Of America
Mail: 4207 SW 34th Street Orlando
Fl 32811-6433
Jim Hawley, Gen Mgr
PH (407) 422-2284 Import & Export
Emp: 11
Cnc machine tool 3541
Edm machine 3541
Plastic injection molding machine 3089

B. B. McCormick Roofing Co.
2520 Vulcan Road Orlando
Mail P. O. Box 7155
Fl 32804
Richard B. Divins, President
Donald Martucci, Vice Pres
PH (407) 295-0012
Fax: (407) 292-3913
Emp: 67
Roofing 2952
Sheet metal 3444

McDonald Air Conditioning, Inc
Mail: 2481 Dineen Ave Orlando
Fl 32804-4289
Dave Webb, Gen Mgr
PH (407) 295-0220
Emp: 30
Sheet metal fabrication 3449

McDowell International Packaging Systems, Inc.
Mail: 5505 Carder Rd. Orlando
Fl 32810-4752
James E. McDowell, Pres
George W. Oglesby, Exec VP
PH (407) 291-2817 Export
Fax: (407) 293-7054
Emp: 50
Carton erector & sealer machine; drop packer 3559
Inverted bottle packer 3559
Five gallon full bottle loader 3559
Bottle packer empty/full; top sealer machine 3559

McMahan Electro-Optics/Engrn. Dept.64
Mail: 2160 Park Ave N. Winter Park
Fl 32789-2310
Barbara G. McMahan, Ceo
Dr. Robert Hall
Mel Call
PH (407) 645-1000 Import & Export
Fax: (407) 644-9000
Emp: 10
Scientific lasers 3821
Eng services for laser systems 8711
Military lasers 3829

Med Genetics Diagnostic Lab
Mail: 807 S Orlando Ave Suite S
Fl 32789-7145 Winter Park
Peter H. Kohn, Phd
John W. McReynolds, Md
PH (407) 628-0744
Emp: 6
Clinical genetic testing r&d lab 8734

Media Design Group Inc
Mail: 1133 W Morse Blvd Winter Park
Fl 32789-3768
PH (407) 628-1755
Emp: 35
(business services nec) 8742
(computers-graphics) 7371

Melaboard Corp
Mail: 6930 Benture Cir. Orlando
Fl 32807
Thomas Potchen, President
PH (407) 671-6065
Emp: 15
Laminating machinery 3559

Meldeau Aircraft Inc
Mail: 2270 N Semoran Blvd Winter Park
Fl 32789
PH (407) 657-2326
Emp: 10
(aircraft manufacturers) 3721

Melweb Signs/Orlando Div.
Mail: P. O. Box 547916 Orlando
Fl 32854-7916
Mark Hansen, Dist Mgr
Curt Long, Plt Supr
PH (407) 849-6150
Emp: 30
Elec. signs, service & installation 3993

Mercer Products Co., Inc.
Mail: 4455 Dardanelle Dr. Orlando
Fl 32808
Christopher S. Paige, VP/Gen Mgr
Cyrus H. Thomas, Plant Mgr
M. Kay Graham, Controller
PH (407) 578-2900 Import & Export
Fax: (407) 578-2888
Toll-Free: 1-800-447-8442
Emp: 115
Pvc & misc. plastic products 3089

Mercury Printers, Inc.
Mail: 1010 Virginia Dr. Orlando
Fl 32803-2576
Murray Schwartz, President
Richard Schwartz, Vice Pres.
PH (407) 894-5963
Emp: 13
Com'l quick printer 2759
Laminating 2891

Merita Division - Interstate Brands Corp.
2200 S. Division Orlando
Mail: P. O. Box 233
Fl 32802-0233
A. L. Brewer
R. D. Welch, Contrl
Joe Czachowski
PH (407) 843-5110
Emp: 600
Baked goods - bread, rolls, cake 2051

Meyers Bakeries, Inc.
Mail: 11321 Satellite Blvd. Orlando
Fl 32821-8494
Moe McGray, Plant Mgr
PH (407) 859-2006
Emp: 55
Bread & rolls 2051

Micro Engineering Inc.
Mail: 1428 Semoran Blvd. Apopka
Fl 32703
Larry Laforest, President
PH (407) 886-4849
Emp: 6
Microelectronics & smd hybrid computing systems 3571
Weapon simulators 8731
Medical 3841

Microlab, Inc.
Mail: 6239 Edgewater Dr Ste A-1
Fl 32810 Orlando
Norman S. Himes
Robert Madden
PH (407) 297-1274
Fax: (407) 297-3566
Emp: 15
Computers-software & service 7371
Computer systems consult/ants/ing 7371
Computer software for banking & finance 7371
Consulting - general 7371

Midstate Legal Supply Company
Mail: P. O. Box 2122 Orlando
Fl 32802-2122
David G. Andreone
Wm G. Newsom, Jr.
PH (407) 299-8220
Emp: 39
Engraving, printing 2759

Mike's Print Shop
Mail: 1241 Miller Ave Winter Park
Fl 32789-4876
Mike Schuermann, Owner
PH (407) 647-0060
Fax: (407) 628-1203
Emp: 9
Offset printing 2752

Miller Machine & Parts Co
Mail: 325 W. Central Orlando
Fl 32801-2587
Ward Keys, Owner
PH (305) 841-3460
Emp: 10
Automotive machine shop 3559

Miller's Custom Kitchens
Mail: 102 W. Crystal Lake St. Orlando
Fl 32806
Robert H. Miller, Owner
PH (407) 425-0761
Emp: 4
Custom cabinets 2434

Mills & Nebrask
Central Florida Lumber & Supply
1602 N Mills Avenue Orlando
Mail. P. O Box 536548
Fl 32853-6548
Tom Pulsifer
Grant Malchow
PH (407) 896-3333
Fax: (407) 897-3821
Emp: 130
Roof & floor trusses 2439
Hollow metal door 2439
Pre-hung wood doors 2439
Lumber & trim 2421

Modern Metal Mfg. Inc
Mail: 20 N Nashville Ave. Orlando
Fl 32805-1796
Irwin Wittick, President
PH (305) 843-3156
Emp 40
Electronic sheet metal housing 3499

Modern Welding Company, Inc.
1801 Atlanta Ave Orlando
Mail P. O Box 568678
Fl 32856-8678
Haskell B Pedigo, VP/Mgr
PH (407) 843-1270 Import & Export
Fax (407) 423-8187
Toll-Free 1-800-641-6789
Emp. 75
Petroleum ind. tanks-plate, fbrglss, coated, alloy 3443
Warehouse steel 3313
Steel plate fabrication 3441
Dredge pontoons, pipe 3531

Mom's Best Cookies
Mail: 6995 Venture Cir. Orlando
Fl 32807-5380
J Wayne Jones, Pres
PH (407) 678-8767
Emp. 50
Cookies and cakes 2052

Monco Of Orlando, Inc.
Mail: 6800 Hanging Moss Orlando
Fl 32807-5327
Thomas M Potchen
John Williamson
PH (407) 671-6065 Import & Export
Fax (407) 678-2102
Emp: 20
Hot roll laminating systems 3559
Edge finishing equipment 3423

Moore Business Forms & Systems Division
Mail 3165 McCrory Place, Ste 180
Fl 32803-3011 Orlando
Barry L. Mestel, Dist. Mgr.
PH (407) 896-7334
Fax. (407) 898-8056
Emp. 11
Business forms & systems 2759
Forms handling equipment 3579

Moore Foundry & Machine Co. Inc.
Mail: 133 W. Kaley Ave. Orlando
Fl 32806-3938
Cecil Moore, President
Jon Moore, Vice Pres.
PH (407) 422-9933
Emp 5
Manhole frames & covers, 3321
Cast iron & steel grates 3446
Heavy machine work 3549

Moran Printing Co.
9125 Bachman Road Orlando
Mail P.O Box 592068
Fl 33859
Michael R. Nofsinger, Vp/Gm
Roland B. Reems, Vice Pres.
C. Roy Groover, Cntroller
PH (407) 859-2030
Fax (407) 826-5284
Toll-Free. 1-800-545-4778
Emp: 88
Commercial printing 2759

Morgan Industries, Inc.
Mail. 8230 El Prado Ave. Orlando
Fl 32825-8298
Chester R. Morgan, President
PH (407) 277-3503
Emp: 13
Box spring frames 2515
Wood shipping crates 2449

Nabisco, Inc.
Mail: 2000 Diversified Way Orlando
Fl 32804-5108
B. R. Tillman, Manager
PH (407) 843-0320
Emp: 33
Bakery products 2051

Namco, Inc.
Mail P.O. Box 14725 Orlando
Fl 32857
Albert Neveu, President
Barbara Maconnell, Vice Pres.
Curtis Neveu, Vice Pres.
PH (407) 277-2385
Emp: 35
Operations extensions systems software 7371
Pre/CAD/CAM component/CA 7374
Classification & retrieval 7374

National Ambulance Builders, Inc.
Mail: 230 N Ortman Dr. Orlando
Fl 32805-1908
Idus E. Willis
Forrest Cheek
PH (407) 299-0064 Export
Toll-Free: 1-407-291-2224
Emp: 82
Ambulances 3711
Light rescue veh. 3711
Wheelchair coaches 3711

National Beverages, Inc Div of Pepsico, Inc.
1700 Directors Row Orlando
Mail: P. O. Box 13889
Fl 32859-3889
Jim Keown, Vp, Gm
Paul Collins, Vp, Fin
Richard Amrozowicz, Secretary
PH (407) 857-3300
Emp: 367
Carbonated beverages 2086

National Electric Coil
Mail 625 W. Pine St. Orlando
Fl 32805-1879
Richard Defelice, Plant Mgr.
PH (407) 423-0555
Toll-Free: 1-800-537-0435
Emp: 34
Repair elec. motors & transformers 3621
New motors 3621

National Sport Sales Inc.
Mail. 1270 Lakeview Dr. Winter Park
Fl 32789-5038
Peter F. Folry, President
PH (407) 671-2930
Emp. 5
Tackle components 3949

National Steel Service Center, Inc.
Mail. 3510 Rio Vista Ave. Orlando
Fl 32805-6696
Richard White, Pltfrm Mgr
PH (407) 849-6170 Import & Export
Fax: (407) 849-6174
Toll-Free: 1-800-432-9282
Emp: 19
Carbon steel flat rolled 3312
Building products 3448
Aluminum 3364

Jim Neal Signs, Inc.
Mail. 725 26th St. Orlando
Fl 32805-5428
Mary Neal, President
Jim Neal, Vice Pres
PH (407) 425-4242
Emp. 3
Commercial signs 3993

Neeley-Built Structures, Inc.
Mail 5250 Clarcona-Ocoee Rd. Orlando
Fl 32810-4056
William F Neeley, President
PH (407) 298-3822
Emp 22
Wooden roof structures 2439

The Newtrend Group
2600 Technology Drive 2 Orlando
Mail: 2600 Technology Drive
Fl 32804-8094
Richard L. Warren, President
Ron Ballenger, Vice Pres
Susan Kirschner, Vice Pres
PH (407) 297-0870
Fax: (407) 292-2528
Emp 305
Banking software, custom applications 7371

Nina Plastic Bags, Inc
7465 Presidents Dr. Orlando
Mail: P.O Box 593433
Fl 32859-3433
S L Sharma, Pres/Gen Mgr
Satish Sharms, Vice Pres
A K Sharma, VP/Plt Mgr
PH (407) 851-6620 Export
Fax: (407) 855-3933
Emp. 65
Polyethylene film, bags & sheeting 3083

Nolco Chemicals,Inc.
Mail 970 Eastbrook Blvd Winter Park
Fl 32792-3014
Scott Kennison, President
PH (407) 671-8646
Emp: 3
Waste water treatment chemicals 2899

Norman Engineering Corporation
Mail: 2579 N Orange Blossom Trail
Fl 32804-4808 Orlando
Anne Belderes
PH (407) 425-6433 Export
Fax: (407) 649-9171
Emp: 7
Precision machine parts 3599
Prototypes 3544
Mil-I-45208 inspection systems 3669

North American Transmission
Mail: 2119 W. Central Blvd. Orlando
Fl 32805-2130
Dayton W. Babcock, President
PH (407) 849-0400
Emp: 5
Automobile and truck transmissions 3714

Odhner Holographics
Mail 833 Laurel Avenue Orlando
Fl 32803-4009
Jefferson Odhner
PH (407) 894-7966
Emp: 1
Lightware tech.,engr.,lab.,scientific and research 3812

Omni Products, Inc.
Mail: 4122 Mercy Industrial Ct. Orlando
Fl 32808-3811
William A Darby, President
PH (407) 299-4950 Export
Toll-Free 1-800-432-8305
Emp. 12
Auto roll-up awnings & r. v. access 2591

Optronic Laboratories, Inc. Kollmorgen Corporation
Mail. 4470 35th St. Orlando
Fl 32811-6590
William E. Schneider, President
PH (407) 422-3171 Export
Fax: (407) 648-5412
Emp. 34
Optical radiation measurement equip 3829
Standards 3825
Calibration services 3423

Orange Business Systems I
Mail. 3541-C Edgewater Dr
Fl 32804-2921
Kay Eckford
PH (407) 298-4876
Emp. 2
Programming services ng)
Turnkey systems-

Orange County Concrete Di
Mail: P.O Box 13377
Fl 32809
Holland Cockcroft, Gen Mgr
PH (407) 855-5274
Emp. 42
Ready mixed concrete
Concrete blocks

Orange Culvert Company
Mail: 301 N. Ivey La.
Fl 32811-4237
Richard W. Moore, President
PH (407) 299-4822
Emp: 12
Culvert pipe
Fabricating

Orange Distributors, Inc.
Mail: 2708 Hazelhurst Ave.
Fl 32804-2794
W. Ronald Cornett, President
Carole Cornett, CPA, Sec/Trea
PH (407) 295-2217 Im
Fax (407) 291-6455
Toll-Free. 1-800-777-6012
Emp: 23
Tapes, pressure sensitive
Tapes, electrical, duct, masking
Straping, steel, plastic

Orange Hearing Aid Center, I
Mail: 1503 S Orange Ave
Fl 32806-2190
PH (407) 849-6520
Emp: 5
Hearing aids and accessories

Orange Shopper
Mail: P. O. Box 771026 W
Fl 34777-1026
John A Lowe, Gen Mgr
PH (407) 656-2342
Emp: 20
Print shopping guide

Orange State Caskets Sales,
Mail. P O. Box 151195
Fl 33684-1195
W. F. Durham, Manager
PH (407) 293-4793
Emp: 6
Wooden & metal burial caskets

Orbital Path Inc.
P.O.Box 3058
Mail: Po. Box 3058
Fl 32790-3058
Thomas Wray
Emp: 10
Space research and technology

Orion Electronics
Mail: 6305 Moore St
Fl 32818-5911
PH (407) 298-5688
Emp 5
(control manufacturers industrial)

Orlando Art Metal
Mail: 2020 W. Washington St.
Fl 32805-1226
Richard Lomerson, President
PH (407) 423-3018
Emp. 3
Burglar bars, security doors
Gates & fences
Railings
Columns & interior iron decoration,

Computer Task Group Inc
Mail: 7600 Southland Blvd Orlando
Fl 32809
PH (407) 859-4801
Emp: 43
(computers-software & service) 7372
(data processing services) 7374

Concurrent Computer Corp/Southern Dev Ctr/ M/S 795
Mail: 2486 Sandlake Road Orlando
Fl 32809-7686
Sanjay Tikku
PH (407) 850-1040
Emp: 18
Develope software ces 7372

Conestoga Toppers
Mail: 5650 W. Colonial Dr. Orlando
Fl 32808-7614
M. Howlett, President
PH (407) 293-1343
Emp: 15
Fiberglass truck tops 3089

Consilium
Mail: 2250 Lucien Way #100 Maitland
Fl 32751-7013
Ken Kline, Ntl Sls Mg
PH (407) 660-1117 Export
Emp: 9
Computer systems for factories 3575
Monitoring & control software 3825

Consolidated Food Management Corp/ dba Romagnola
Mail: 2720 N. Forsyth Rd. Winter Park
Fl 32792
Herbert Prokscha
Peter Fuchs
PH (407) 679-1907 Import & Export
Fax: (407) 657-0168
Emp: 45
Pasta products 2098

Contemporary Panels, Inc.
Mail: 965 Taft Vineland Rd. Orlando
Fl 32824-8004
Clifford L. Wonderly, President
Scott Wonderly, VP/Sales
PH (407) 885-4890 Export
Fax: (407) 857-1786
Emp: 12
Cooler/freezer insul bldg panels 3449

Continental Baking Co.
Mail: 2530 N. Orange Blossum Trail
Fl 32804-4807 Orlando
Jim Minto, Branch Mgr
PH (407) 423-7131
Emp: 42
Bakery products 2052

Continental Can Co. Inc.
Mail: P. O. Box 369 Winter Garden
Fl 32787
C. D. Turner, Plant Mgr.
PH (407) 656-2224 Export
Emp: 140
Tin cans 3411

Contractors Equipment Rental Co. Dealco
1331 W. Central Blvd. Orlando
Mail: P. O. Box 3542
Fl 32802-3542
Troy Deal, Jr
Gene Pashuck
PH (407) 849-6420
Toll-Free: 1-800-432-4745
Emp: 32
Electronic security systems 3669
Construction equipment rental 3531

Control Laser Corp. Quantronix Corp.
Mail: 7503 Chancellor Dr. Orlando
Fl 32809-8505
J. Richard Crowley, Pres
David Montes, Nat'l Sls Mgr
PH (407) 438-2500 Import & Export
Fax: (407) 851-2720
Toll-Free: 1-800-327-6036
Emp: 80
Laser systems 3669
Lasers 3845

Control Micro Systems Inc.
6961 Hanging Moss Road Orlando
Mail: 6991 Hanging Moss Road
Fl 32807-5329
PH (407) 679-9716
Emp: 5
Computer software svcs 7372
Industrial laser control systems 3812
Laser marker kits 3812

E. D. Cook Lumber Company
Mail: 5901 Beggs Rd. Orlando
Fl 32810-2656
G. V. Cook, President
Harry Aroian, Vice Pres
Michael Guarnein
PH (407) 293-1811
Fax: (407) 241-2865
Emp: 7
Pressure treat wood 2491

Cookin' Good - Showell Farms, Inc./ Of Florida
210 East Story Rd Ocoee
Mail: P. O. Box 847
Fl 34761-0847
Don Muth, Manager
Gail Mott
PH (407) 656-2631
Emp: 13
Chicken, turkey & duck 2015

Correct Craft, Inc.
Mail: 6100 S. Orange Avenue Orlando
Fl 32809
Walter N. Meloon, CEO/Pres
PH (407) 855-4141 Export
Fax: (407) 851-7844
Emp: 170
Mfg. boats & trailers 3731

Cortez, Inc.
700 Roper Parkway Ocoee
Mail: P. O. Box 25
Fl 34761-0025
Ed Cortez, President
Donna Cortez, Vice Pres.
PH (407) 656-4397
Fax: (407) 656-4557
Emp: 30
Design,instal & fabr. proces. equip 3498

Counterforce Electronic Security, Inc. Deal Co., Inc.
Mail: 1331 W. Central Blvd. Orlando
Fl 32805-1794
Gene Pashuck
Joe Oppelt, Jr
PH (407) 849-6426 Export
Toll-Free: 1-800-432-4745
Emp: 15
Complete security systems 3669

Crawford Equipment & Engineering
436 W. Landstreet Road Orlando
Mail: P. O. Box 593243
Fl 32859-3243
Jim Crawford, Owner
Steve Atkinson, Gen Mgr
PH (407) 851-0993 Export
Fax: (407) 851-2406
Toll-Free: 1-800-228-0884
Emp: 27
MFG incineration equipment 3433
Cremation equipment 3569
Water scrubbers 3589

Creative Computer Center
Mail: 1225 E Colonial Drive Orlando
Fl 32803-4779
J. M. Gibson, Owner
PH (407) 894-0789
Emp: 18
Dev computer software 7372
Apple, McIntosh, Epson computer sftwre accessories 7379

Creative Engineering, Inc.
Mail: 47 W. Jefferson Orlando
Fl 32801-1882
Aaron Fechter
Melvin A. Fechter
Alice Ann Doiron
PH (407) 425-1001 Export
Fax: (407) 425-1007
Emp: 9
Animated robots 3679

Creative Packaging, Inc.
Mail: 611 Robinson St. W. Orlando
Fl 32801-1797
Jack C. Simms, President
PH (407) 422-2579
Emp: 4
Conv. of packaging films & foils 3569
Converters of polyethelene 3089
Printers, bagmakers 3089

Cress Chemical & Equipment Co., Inc.
Mail: 1043 S. Orange Blossom Trail
Fl 32805-3739 Orlando
Warren Cressman, President
Stephen L. Cressman
PH (407) 425-2846
Toll-Free: 1-800-226-6222
Emp: 4
Cleaning supplies, fleet & auto pressure washers 3663

Crystal Water Co Inc
Mail: 3500 Silver Star Rd. Orlando
Fl 32808-4624
John Houser, Div Mgr
Paul Coe, Plant Mgr
PH (407) 298-0180
Emp: 80
Bottled water 2086

Cues, Inc.
Mail: 3501 Vineland Rd. Orlando
Fl 32811-6484
Henry B. Lange, Pres
W. Huber, Vice Pres
PH (407) 849-0190 Export
Emp: 97
Sewer maintenance equipment 3589
Closed circuit tv equipment sewer environment 3663
Closed circuit tv equipment industrial 3663

Cuisine Des Chefs
Mail: 2441 Orlando Central Pkwy.
Fl 32809-5654 Orlando
Michael Neuner, Exec Mgr
Holly Cooper
PH (407) 851-2213 Import & Export
Fax: (407) 851-6595
Emp: 80
Bakery products 2051

Currys Printing Co. Inc.
Mail: 544 W. Central Blvd. Orlando
Fl 32801-2591
Larry Laffler, President
PH (407) 425-1685
Emp: 6
Commercial printing - offset 2752

Curtis 1000, Inc.
Mail: P. O. Box 593200 Orlando
Fl 32859-3200
James W. Miller, Div Mgr
PH (407) 855-8320
Fax: (407) 851-1229
Emp: 80
Printing envelopes & business forms 2759

Custom Cable Industries
Mail: 2221 Lee Rd.
Fl 32789-1868
Tom Oden, Gen Mgr
Steve Weimen
Marilyn Smith
PH (407) 629-2112
Emp: 42
Computer cables

Custom Craft Bindery
Mail: 2309 N. Orange Ave.
Fl 32804-5510
Jerry D. Snider, Owner
PH (407) 898-4701
Emp: 4
Book binder & restoration

Custom Metal Designs, Inc.
17316 State Hwy 438 West
W
Mail: P.O. Box 771034
Fl 34777-1034
Saul Grimes, President
PH (407) 656-7771 Imp
Fax: (407) 656-6230
Toll-Free: 1-800-334-1777
Emp: 30
Cable conveyors
Case conveyors
Can conveyors

Custom Research, Inc.
4815-B W Colonial Dr
Mail: P. O. Box 536
Winter Park, Fl 32790-05
Burt Bell, President
Donna W. Bell, Sec/Treas
PH (407) 298-7804 Imp
Fax: (407) 578-0396
Emp: 6
Business consulting services
Envrnmntl rooms/refrig incubat
crime lab chmbr
Microprocessor controllers
New product research

D & G Enterprises
Mail: Box 15832
Fl 32858
David Goings
Emp: 0
Business consulting services

Damar Machine & Tool
Mail: 18409 11th Ave
Fl 32833-3340
Steve Samarga, President
PH (407) 568-2911
Emp: 4
Precision aircraft parts

Damon Corporation
Mail: 255 N Lakemont Ave
Fl 32792
PH (407) 644-1555
Emp: 30
Commercial testing laboratories

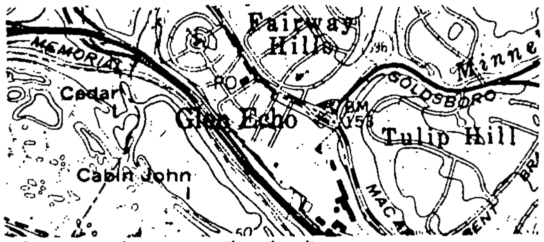
Daniels & Associates Inc
Mail: 135 Wall St Ste 102
Fl 32801-4609
Henry A. Goldstein
Robert Johnson
PH (407) 648-4815
Emp: 5
(computer software svcs)
Paging
Cellular phones

Daniels Mfg. Corporation
Mail: 6103 Anno Ave.
Fl 32809-5099
George G. Daniels, President
Dave Kelly, Sales/Mktg
PH (407) 855-6161 Exp
Emp: 153
Crimping tools
Electronic connector accessorie
Connector service kits

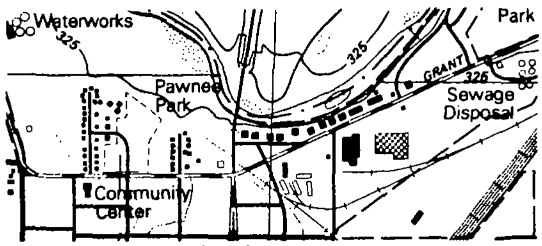
National Mapping Program

Topographic Map Symbols

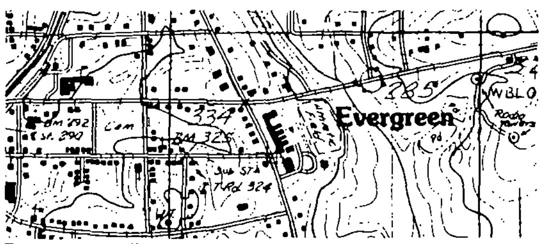
National Large Scale Series



1:24,000 scale—conventional units



1:25,000 scale—metric units



Provisional edition

U. S. Department of the Interior
Geological Survey
National Mapping Division

Map series and quadrangles

Each map in a U. S. Geological Survey series conforms to established specifications for size, scale, content, and symbolization. Except for maps which are formatted on a County or State basis, USGS quadrangle series maps cover areas bounded by parallels of latitude and meridians of longitude.

Map scale

Map scale is the relationship between distance on a map and the corresponding distance on the ground. Scale is expressed as a ratio, such as 1:25,000, and shown graphically by bar scales marked in feet and miles or in meters and kilometers.

Standard edition maps

Standard edition topographic maps are produced at 1:20,000 scale (Puerto Rico) and 1:24,000 or 1:25,000 scale (conterminous United States and Hawaii) in either 7.5 x 7.5- or 7.5 x 15-minute format. In Alaska, standard edition maps are available at 1:63,360 scale in 7.5 x 20 to 36-minute quadrangles. Generally, distances and elevations on 1:24,000-scale maps are given in conventional units: miles and feet, and on 1:25,000-scale maps in metric units: kilometers and meters.

The shape of the Earth's surface, portrayed by contours, is the distinctive characteristic of topographic maps. Contours are imaginary lines which follow the land surface or the ocean bottom at a constant elevation above or below sea level. The contour interval is the elevation difference between adjacent contour lines. The contour interval is chosen on the basis of the map scale and on the local relief. A small contour interval is used for flat areas; larger intervals are used for mountainous terrain. In very flat areas, the contour interval may not show sufficient surface detail and supplementary contours at less than the regular interval are used.

The use of color helps to distinguish kinds of features:

Black – cultural features such as roads and buildings.
Blue – hydrographic features such as lakes and rivers.
Brown – hypsographic features shown by contour lines.
Green – woodland cover, scrub, orchards, and vineyards.
Red – important roads and public land survey system.
Purple – features added from aerial photographs during map revision. The changes are not field checked.

Some quadrangles are mapped by a combination of orthophotographic images and map symbols. Orthophotographs are derived from aerial photographs by removing image displacements due to camera tilt and terrain relief variations. An orthophotoquad is a standard quadrangle format map on which an orthophotograph is combined with a grid, a few place names, and highway route numbers. An orthophotomap is a standard quadrangle format map on which a color enhanced orthophotograph is combined with the normal cartographic detail of a standard edition topographic map.

Provisional edition maps

Provisional edition maps are produced at 1:24,000 or 1:25,000 scale (1:63,360 for Alaskan 15-minute maps) in conventional or metric units and in either a 7.5 x 7.5- or 7.5 x 15-minute format. Map content generally is the same as for standard edition 1:24,000- or 1:25,000-scale quadrangle maps. However, modified symbolism and production procedures are used to speed up the completion of U.S. large-scale topographic map coverage.

The maps reflect a provisional rather than a finished appearance. For most map features and type, the original manuscripts which are prepared when the map is compiled from aerial photographs, including hand lettering, serve as the final copy for printing. Typeset lettering is applied only for features which are designated by an approved name. The number of names and descriptive labels shown on provisional maps is less than that shown on standard edition maps. For example, church, school, road, and railroad names are omitted.

Provisional edition maps are sold and distributed under the same procedures that apply to standard edition maps. At some future time, provisional maps will be updated and reissued as standard edition topographic maps.

National Mapping Program indexes

Indexes for each State, Puerto Rico, the U. S. Virgin Islands, Guam, American Samoa, and Antarctica are available. Separate indexes are available for 1:100,000-scale quadrangle and county maps; USGS/Defense Mapping Agency 15-minute (1:50,000-scale) maps; U. S. small scale maps (1:250,000, 1:1,000,000, 1:2,000,000 scale; State base maps; and U. S maps); land use/land cover products; and digital cartographic products.

Series	Scale	1 inch represents approximately	1 centimeter represents	Size (latitude x longitude)	Area (square miles)
Puerto Rico 7.5-minute	1:20,000	1,667 feet	200 meters	7.5 x 7.5 min.	71
7.5-minute	1:24,000	2,000 feet (exact)	240 meters	7.5 x 7.5 min.	49 to 70
7.5-minute	1:25,000	2,083 feet	250 meters	7.5 x 7.5 min.	49 to 70
7.5 x 15-minute	1:25,000	2,083 feet	250 meters	7.5 x 15 min.	98 to 140
USGS/DMA 15-minute	1:50,000	4,166 feet	500 meters	15 x 15 min.	197 to 282
15-minute	1:62,500	1 mile	625 meters	15 x 15 min.	197 to 282
Alaska 1:63,360	1:63,360	1 mile (exact)	633.6 meters	15 x 20 to 36 min.	207 to 281
County 1:50,000	1:50,000	4,166 feet	500 meters	County area	Varies
County 1:100,000	1:100,000	1.6 miles	1 kilometer	County area	Varies
30 x 60-minute	1:100,000	1.6 miles	1 kilometer	30 x 60 min.	1,568 to 2,240
U. S. 1:250,000	1:250,000	4 miles	2.5 kilometers	1° x 2° or 3°	4,580 to 8,669
State maps	1:500,000	8 miles	5 kilometers	State area	Varies
U. S. 1:1,000,000	1:1,000,000	16 miles	10 kilometers	4° x 6°	73,734 to 102,759
U. S. Sectional	1:2,000,000	32 miles	20 kilometers	State groups	Varies
Antarctica 1:250,000	1:250,000	4 miles	2.5 kilometers	1° x 3° to 15°	4,089 to 8,336
Antarctica 1:500,000	1:500,000	8 miles	5 kilometers	2° x 7.5°	28,174 to 30,462

How to order maps

Mail orders. Order by map name, State, and series/scale. Payment by money order or check payable to the U. S. Geological Survey must accompany your order. Your complete address, including ZIP code, is required.

Maps of areas *east* of the Mississippi River, including Minnesota, Puerto Rico, the Virgin Islands of the United States, and Antarctica.	Eastern Distribution Branch U. S. Geological Survey 1200 South Eads Street Arlington, VA 22202
Maps of areas *west* of the Mississippi River, including Alaska, Hawaii, Louisiana, American Samoa, and Guam.	Western Distribution Branch U. S. Geological Survey Box 25286, Federal Center Denver, CO 80225

A single order combining both eastern and western maps may be placed with either office.

Residents of Alaska may order Alaska maps or an index for Alaska from the Alaska Distribution Section, U. S. Geological Survey, New Federal Building – Box 12, 101 Twelfth Avenue, Fairbanks, AK 99701.

Sales counters. Maps of the area may be purchased over the counter at the following U. S. Geological Survey offices.

Alaska	Anchorage	Room 108, Skyline Building, 508 Second Avenue
	Fairbanks	Room 126, New Federal Building, 101 Twelfth Avenue
California	Los Angeles	Room 7638, Federal Building, 300 North Los Angeles Street
	Menlo Park	Room 122, Building 3, 345 Middlefield Road
	San Francisco	Room 504, Custom House, 555 Battery Street
Colorado	Denver	Building 41, Federal Center
	Denver	Room 169, Federal Building, 1961 Stout Street
District of Columbia	Washington	Room 1028, General Services Administration Bldg., 19th and F Sts. NW
Missouri	Rolla	1400 Independence Road
Texas	Dallas	Room 1C45, Federal Building, 1100 Commerce Street
Utah	Salt Lake City	Room 8105, Federal Building, 125 South State Street
Virginia	Arlington	1200 South Eads Street
	Reston	Room 1C402, National Center, 12201 Sunrise Valley Drive
Washington	Spokane	Room 678, U. S. Court House, West 920 Riverside Avenue

Commercial dealers. Names and addresses of dealers are listed in each State index. Commercial dealers sell U. S. Geological Survey maps at their own prices.

	Conventional unit maps	Metric unit maps	Provisional edition maps - metric or conventional units
CONTROL DATA AND MONUMENTS			
Aerial photograph roll and frame number	Not Shown	Not Shown	3-20
Horizontal control:			
Third order or better, permanent mark	Neace	Neace	Neace
With third order or better elevation	BM 148	BM 45.1	Pike BM 45.1
Checked spot elevation	64	19.5	Not Shown
Coincident with section corner	Cactus	Cactus	Cactus
Unmonumented	Not Shown	Not Shown	
Vertical control:			
Third order or better, with tablet	BM 53	BM 16.3	BM 53.4
Third order or better, recoverable mark	394	120.0	393.6
Bench mark at found section corner	BM 61	BM 18.6	BM 60.9
Spot elevation	17	5.3	17
Boundary monument:			
With tablet	BM 71	BM 21.6	BM 71
Without tablet	562	171.3	562
With number and elevation	67 988	67 301.1	67 988
U.S. mineral or location monument			USMM
BOUNDARIES			
National			
State or territorial			
County or equivalent			
Civil township or equivalent			
Incorporated city or equivalent			
Park, reservation, or monument			
Small park			
LAND SURVEY SYSTEMS			
U.S. Public Land Survey System:			
Township or range line			
Location doubtful			
Section line			
Location doubtful			
Found section corner; found closing corner			
Witness corner; meander corner	WC MC	WC MC	WC MC

	Conventional unit maps	Metric unit maps
Other land surveys:		
Township or range line		
Section line		
Land grant or mining claim; monument		
Fence line		
ROADS AND RELATED FEATURES		
Primary highway		
Secondary highway		
Light duty road		
Unimproved road		
Trail		
Dual highway		
Dual highway with median strip		
Road under construction		
Underpass; overpass		
Bridge		
Drawbridge		
Tunnel		
BUILDINGS AND RELATED FEATURES		
Dwelling or place of employment: small; large		
School; church		
Barn, warehouse, etc.: small; large		
House omission tint		
Racetrack		
Airport		
Landing strip		
Well (other than water); windmill		
Water tank: small; large		
Other tank: small; large		
Covered reservoir		
Gaging station		
Landmark object		
Campground; picnic area		
Cemetery: small; large	Cem	Cem

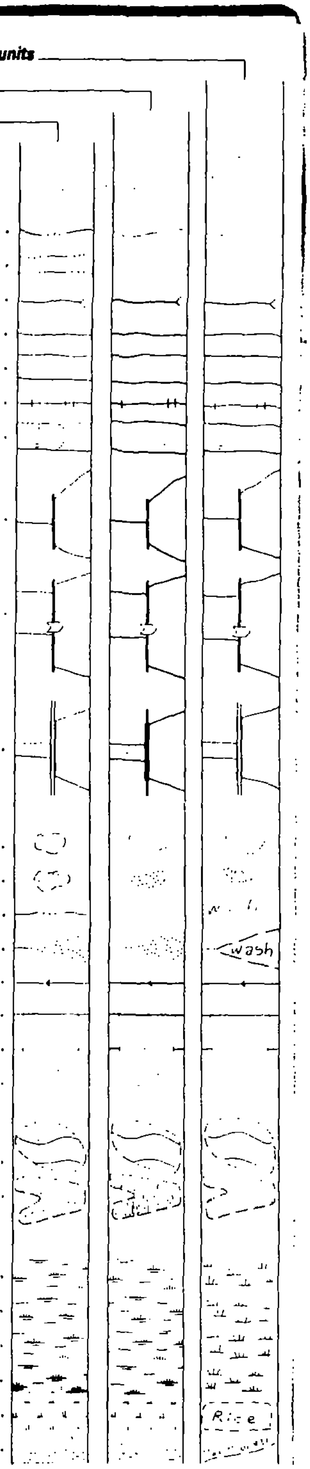
	Conventional unit maps	Metric unit maps	Provisional edition maps - metric or conventional units
RAILROADS AND RELATED FEATURES			
Standard gauge single track; station			
Standard gauge multiple track			
Abandoned			
Under construction			
Narrow gauge single track			
Narrow gauge multiple track			
Railroad in street			
Juxtaposition			
Roundhouse and turntable			
TRANSMISSION LINES AND PIPELINES			
Power transmission line; pole; tower			Trans Line
Telephone or telegraph line			Telephone
Aboveground oil or gas pipeline			Pipeline Aboveground
Underground oil or gas pipeline			Pipeline
CONTOURS			
Topographic:			
Intermediate			
Index			
Supplementary			
Depression			
Cut; fill			
Bathymetric:			
Intermediate			
Index			
Primary			Not Shown
Index Primary			
Supplementary			
MINES AND CAVES			
Quarry or open pit mine			
Gravel, sand, clay, or borrow pit			
Mine tunnel or cave entrance			
Prospect; mine shaft			
Mine dump			Mine dump
Tailings			Tailings

	Conventional unit maps	Metric unit maps	Provisional edition maps - metric or conventional units
SURFACE FEATURES			
Levee			Levee
Sand or mud area, dunes, or shifting sand			Sand
Intricate surface area			Strip Mine
Gravel beach or glacial moraine			Gravel
Tailings pond			Tailings Pond
VEGETATION			
Woods			
Scrub			
Orchard			
Vineyard			
Mangrove			
MARINE SHORELINE			
Topographic maps:			
Approximate mean high water			
Indefinite or unsurveyed			
Topographic-bathymetric maps:			
Mean high water			Not Show
Apparent (edge of vegetation)			
COASTAL FEATURES			
Foreshore flat			Mud
Rock or coral reef			Rock
Rock bare or awash			
Group of rocks bare or awash			
Exposed wreck			Not Sh
Depth curve; sounding	10	3	
Breakwater, pier, jetty, or wharf			
Seawall			
BATHYMETRIC FEATURES			
Area exposed at mean low tide; sounding datum			
Channel			Nc Sho
Offshore oil or gas: well; platform			
Sunken rock			

Provisional edition maps - metric or conventional units

Metric unit maps

Conventional unit maps



RIVERS, LAKES, AND CANALS

Intermittent stream

Intermittent river

Disappearing stream

Perennial stream

Perennial river

Small falls; small rapids

Large falls; large rapids

Masonry dam

Dam with lock

Dam carrying road

Intermittent lake or pond

Dry lake

Narrow wash

Wide wash

Canal, flume, or aqueduct with lock

Elevated aqueduct, flume, or conduit

Aqueduct tunnel

Water well; spring or seep

GLACIERS AND PERMANENT SNOWFIELDS

Contours and limits

Form lines

SUBMERGED AREAS AND BOGS

Marsh or swamp

Submerged marsh or swamp

Wooded marsh or swamp

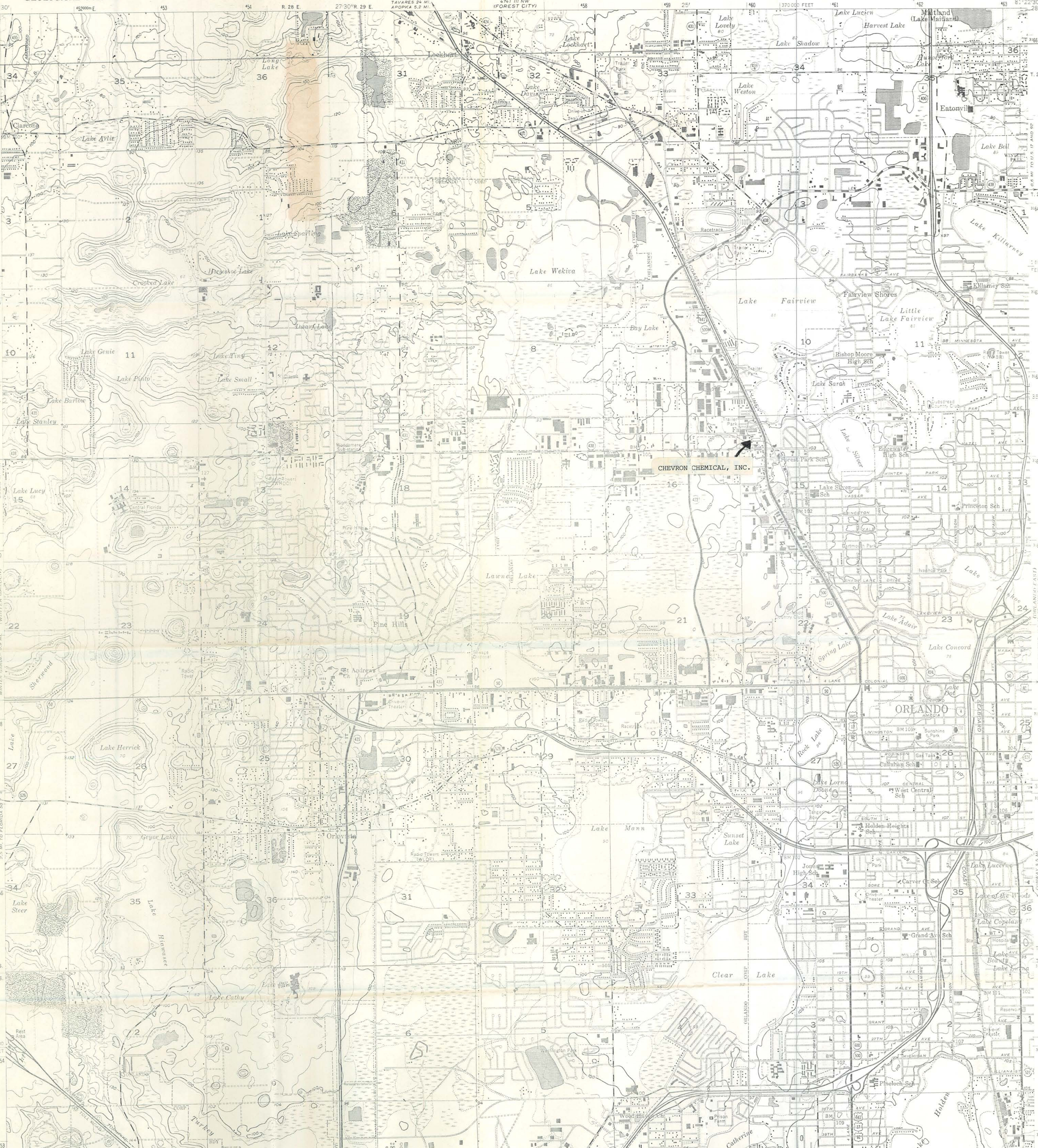
Submerged wooded marsh or swamp

Rice field

Land subject to inundation

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

ORLANDO WEST QUADRANGLE
FLORIDA—ORANGE CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USGS, USC&GS, and Florida Geodetic Survey

Topography from aerial photographs by Kelsh plotter
Aerial photographs taken 1954. Field check 1956

Polyconic projection
10,000-foot grid based on Florida coordinate system, east zone
1000-meter Universal Transverse Mercator grid ticks,
zone 17, shown in blue. 1927 North American Datum
To place on the predicted North American Datum 1983
move the projection lines 27 meters south and
19 meters west as shown by dashed corner ticks

Red tint indicates areas in which only landmark buildings are shown

Revisions shown in purple compiled from aerial photographs
taken 1977 and other source data. This information not
field checked. Map edited 1980

Purple tint indicates extension of urban areas

MN GN 2° 36 MILS 0°13′ 4 MILS

UTM GRID AND 1980 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

FLORIDA

QUADRANGLE LOCATION

Reference 22

ROAD CLASSIFICATION

Heavy-duty — Light-duty
Medium-duty — Unimproved dirt

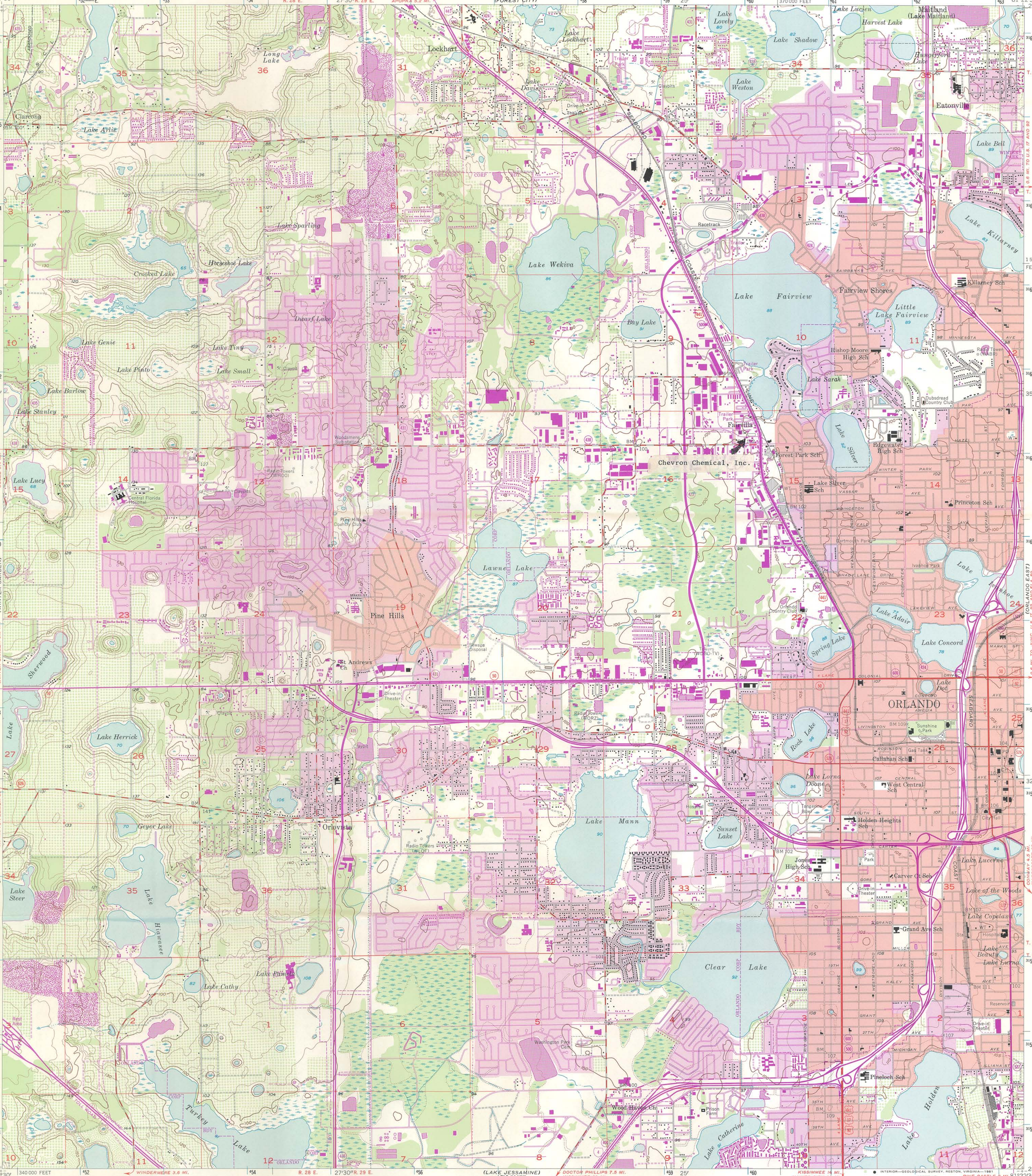
Interstate Route — U. S. Route — State Route

ORLANDO WEST, FLA.
N2830—W8122.5/7.5

1956
PHOTOREVISED 1980
DMA 4741 III SW—SERIES V847

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

ORLANDO WEST QUADRANGLE
FLORIDA—ORANGE CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USGS, USC&GS, and Florida Geodetic Survey

Topography from aerial photographs by Kelsh plotter
Aerial photographs taken 1954. Field check 1956

Polyconic projection
10,000-foot grid based on Florida coordinate system, east zone
1000-meter Universal Transverse Mercator grid ticks,
zone 17, shown in blue. 1927 North American Datum
To place on the predicted North American Datum 1983
move the projection lines 27 meters south and
19 meters west as shown by dashed corner ticks

Red tint indicates areas in which only landmark buildings are shown

Revisions shown in purple compiled from aerial photographs taken 1977 and other source data. This information not field checked. Map edited 1980

Purple tint indicates extension of urban areas

UTM GRID AND 1980 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

Reference 22

ROAD CLASSIFICATION

Heavy-duty | Light-duty
Medium-duty | Unimproved dirt

Interstate Route | U. S. Route | State Route

ORLANDO WEST, FLA.
N2830—W8122.5/7.5

1956
PHOTOREVISED 1980
DMA 4741 III SW—SERIES V847

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1981

Ref. 23

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV

345 COURTLAND STREET, N.E.
ATLANTA, GEORGIA 30365

TELEPHONE MEMORANDUM

CALL MADE BY: Cynthia K. Gurley
DATE OF CALL: April 23, 1993
TIME OF CALL: 1000

SIGNATURE/DATE: Cynthia K. Gurley 4/23/93
FACILITY: Chevron Chemical Co.
EPA ID No.: FLD004064242

PERSON CONTACTED: Mr. Thomas L. Stephens
TITLE/POSITION: Vice President of Savannah Laboratories
ORGANIZATION: Savannah Laboratories
TELEPHONE NUMBER: (904) 878-3994

SUBJECT: The laboratory techniques when analyzing environmental samples at the Savannah Laboratories.

SUMMARY OF CONVERSATION:

Environmental samples obtained during a Contamination Assessment by Brown and Caldwell Consultants at the Chevron Chemical site were analyzed by Savannah Laboratories in Tallahassee, Florida in October of 1990. This data can be located in Reference 3, Appendix C.

Mr. Stephens, who was the project manager at the laboratory for this group of samples, explained that if a concentration was not detected in a sample then the Practical Quantitation Limit (PQL) for that sample was recorded on the data sheets. The PQL is similar to the Contract Required Quantitation Limit (CRQL) in addition, the PQL is ten times the Method Detection Limit (MDL).

REFERENCE 24

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV

345 COURTLAND STREET, N.E.
ATLANTA, GEORGIA 30365

DATE: April 22, 1993

SUBJECT: Ground Water Classification of the Shallow Aquifer at the Chevron Chemical Facility, Orlando, Florida

FROM: Lee Thomas, Hydrologist
Ground Water Technology Support Unit LAT

THROUGH: David W. Hill, Chief David W. Hill
Ground Water Technology Support Unit

TO: Dorothy L. Rayfield
South Unit, Site Assessment Section

The surficial aquifer at the Chevron Chemical Facility in Orlando, Florida was classified as a Class II aquifer, A Potential Source of Drinking Water, in the February 3, 1993 memorandum from me to you. As you requested, this memorandum is to provide additional information on this classification. The technical basis for the classification is Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy, Final Draft, December 1986, Office of Ground Water Protection. The regulatory basis for the classification is the requirement under 40 CFR 300.430(e)(2)(i)(B) that ground water be classified so that remedial goals can be established. Under this classification system the water in an aquifer is classified, at a minimum, as Class II if the aquifer will yield 150 gpd and has less than 10,000 ppm total dissolved solids under ambient conditions. Although there is, to our knowledge, no site specific data for the properties of the surficial aquifer, regional information indicates that this aquifer would meet this criteria. In Water Resources of Orange County, Florida, Florida Division of Geology Report of Investigations # 50, information is provided on the yield of the nonartesian aquifer for the county in which this site is located for water supply wells. The nonartesian zone would represent the uppermost aquifer zone since it is the water table aquifer and it appears that this zone is likely to be representative of the surficial aquifer at this site. Although the report indicates that there are local areas where the aquifer does not yield much water, most wells are indicated to yield 5 to 10 gpm, well in excess of the 150 gpd criteria. Also, if a well is used for a water supply well its waters would certainly have a TDS content of less than 10,000 ppm. Based on the information that is available it appears reasonable to assume that the waters of the surficial aquifer would meet the criteria to be classified as a Class II ground water.

Hopefully these comments will be useful as you review the ground water data on this site, if there are any questions, please contact me at x3866.

United States
Environmental Protection
Agency

Office of Ground-Water
Protection (WH-550G)
Washington, DC 20460

December 1986

THOMAS

Water

EPA

Guidelines for Ground-Water Classification under the EPA Ground-Water Protection Strategy

Final Draft

GUIDELINES FOR GROUND-WATER CLASSIFICATION UNDER THE EPA GROUND-WATER PROTECTION STRATEGY

FINAL DRAFT

NOVEMBER 1986

OFFICE OF GROUND-WATER PROTECTION
OFFICE OF WATER

U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

EXECUTIVE SUMMARY

PART I

Introduction

The Environmental Protection Agency (EPA) issued its Ground-Water Protection Strategy in August, 1984. This guidance document for ground-water classification is a follow-up to the Strategy, and is a major step in EPA's efforts to provide policy direction for EPA programs with ground water responsibility. The purpose of this document is two-fold: (1) to further define the classes, concepts, and key terms related to the classification system outlined in the Ground-Water Protection Strategy, and (2) to describe the procedures and information needs for classifying ground water. Through the release of the Draft Guidelines, public comment is being solicited on the appropriate direction to meeting these purposes.

Through the process of classification, ground-water resources are separated into hierarchical categories on the basis of their value to society, use, and vulnerability to contamination. Ground-water classes will be a factor in deciding the level of protection or remediation the resource will be provided.

Background

The core of the Ground-Water Protection Strategy is a differential protection policy that recognizes that different ground waters require different levels of protection. A three-tiered classification system was established as the vehicle for implementing this policy.

The classification system will, as appropriate, be implemented by EPA program offices and state agencies responsible for EPA delegated programs as changes in program guidance and regulation are made. The differential protection policy, as expressed through the classification system, will assist the programs in tailoring protection policies for ground water. In permit-based actions concerning point sources of pollution, classification will most likely become an additional step in site-specific analysis. Similarly, EPA is considering various approaches for using differential protection and other strategy-related policies for broader-based, nonpoint sources. Two recent EPA rule-making actions-

ACKNOWLEDGEMENTS

The guidelines were prepared by the Office of Ground-Water Protection under the overall guidance of the Director, Marian Mlay. The project manager was Ron Hoffer, with additional technical support provided by Jose Valdes. Assistance in developing the socioeconomic and ecological aspects of the system was provided by Brendan Doyle and Arthur Koines of the Office of Policy Planning and Evaluation. Much of their effort led to a set of supporting analyses which, while unpublished, were valuable in framing options. Joyce Edwards of OGWP helped in the secretarial and logistical aspects of this document from the inception of the project.

Technical consultants played a significant role in the preparation of these guidelines. The primary technical consultant was Geraghty & Miller, Inc. (G&M), Dr. William Doucette, project manager. Other members of the G&M support team included Michael Gaudette, Bonnie Halberstam, Caroline Hoover, Don Lundy, Paula Magnuson, Jeffrey Mahan, and Jeffrey Sgambat. Gloria Hall at G&M performed the majority of word processing. Subcontract assistance was provided by ICF, Inc., Paul Bailey, project manager. Other ICF support team members were Craig Dean, Janis Edwards, and Liane Heatherington.

The efforts of the Classification Guidelines Work Group are especially appreciated. Serving with representatives of the EPA program offices and EPA Regions were Robert Moore of the Connecticut Department of Environmental Protection, Edith Tanenbaum of the Long Island Regional Planning Board, Rodney DeHan of the Florida Department of Environmental Regulation, Maxine Goad of the New Mexico Department of Health, and John Moore of the U.S. Geological Survey. The technical and policy insight of all the work group members helped immeasurably to carry through the spirit of the EPA Ground Water Protection Strategy. Any shortcomings in this document, should not, however, be attributed to the work group members as individuals.

- one for Superfund and one for radioactive waste disposal-- incorporated aspects of the classification system. Other EPA program offices are in different stages of developing approaches to implementing the system. It is important to note that the Guidelines are not enforceable in particular EPA programs until legally incorporated by program guidance regulations, or other appropriate means.

State agencies responsible for managing ground water will not be required by EPA to adopt the classification system for general program use. In fact, many states have already developed ground-water protection approaches tailored to their particular land use and hydrogeologic conditions. However, state agencies carrying out delegated or authorized EPA programs may need to use these guidelines as they are implemented by those programs.

It should be noted that a site located in a designated Safe Drinking Water Act Sole Source Aquifer (SSA) is not automatically placed in Class I. The criteria for SSAs are less rigorous than those of Class I. Greater rigor is needed for classification since, unlike SSAs, Class I will be a decision-making factor in program regulations. SSAs are only considered at the Federal level under financially assisted projects such as farm loans and rural water districts.

At least half of the states are using, or are seriously considering using, some form of a site-by-site or anticipatory classification system. Under its existing programs, EPA will perform site-by-site rather than aquifer or well field classification. However, the classification system presented in this guidelines document attempts to be generally consistent with broader classification systems that may be used by the states. EPA is considering the substitution of state ground-water classification systems for the EPA system wherever possible. In the implementation of its ground-water protection programs, EPA will consider and incorporate, to the extent possible, State Wellhead Protection Areas approved under the Safe Drinking Water Act Amendments of 1986.

<u>The EPA Ground-Water Classification System</u>

The EPA Ground-Water Classification System consists of three general classes of ground water representing a hierarchy of ground-water resource values to society. These classes are:

- Class I - Special ground water

- Class II - Ground water currently and potentially a source for drinking water
- Class III - Ground water not a source of drinking water.

The classification system is, in general, based on drinking water as the highest beneficial use of the resource. The system is designed to be used in conjunction with the site-by-site assessments typically conducted by the EPA program offices in issuing permits and deciding on appropriate remedial action.

Classification Review Area:

A site-by-site approach to classifying ground water necessitates delineating a segment of ground water to which the classification criteria apply. Since EPA is not classifying ground water on a regional or aquifer-specific basis, a Classification Review Area concept is incorporated as a key element in the classification decision. This is, however, strictly an area for review of ground-water characteristics and <u>not</u> an area where regulation will be imposed beyond that of the specific activity under consideration.

The Classification Review Area is delineated based initially on a two-mile radius from the boundaries of the "facility" or the "activity." An expanded Classification Review Area is allowed under certain hydrogeolgoic conditions. Within the Classification Review Area, a preliminary inventory of public water-supply wells, populated areas not served by public supply, wetlands, and surface waters, is performed. The classification criteria are then applied to the Classification Review Area and a classification determination made.

Subdivision of Classification Review Area and Interconnection Concepts:

Where hydrogeologic data are available, the Classification Review Area can be subdivided to reflect the presence of naturally occuring ground-water bodies that may have significantly different use and value. These ground-water bodies, referred to as "ground-water units", must be characterized by a degree of interconnection (between adjacent ground-water units) such that an adverse change in water quality to one ground-water unit will have little likelihood of causing an adverse change in water quality in the adjacent ground-water unit. Each ground-water unit can be treated as a separate subdivision of the Classification Review Area. A classification decision is made only for the ground-water unit or units potentially impacted by the activity.

The identification of ground-water units and assessment of interconnection between ground-water units may, in critical cases, require a rigorous hydrogeologic analysis. The acceptance of subdivisions will be on a case-by-case basis after review of the supporting analysis.

The recognition of ground-water unit subdivisions to the Classification Review Area establishes a spatial limit for classification and the application of protective management practices. The degree of interconnection to adjacent ground-water units and surface waters is also a criterion for differentiating between subclasses of Class III ground waters.

Ground-water units are mappable, three-dimensional ground-water bodies delineated on the basis of the three types boundaries described below:

Type 1: Permanent ground-water flow divides

Type 2: Extensive, low-permeability (non-aquifer) geologic units (e.g., thick, laterally extensive confining beds) especially where characterized by favorable hydraulic head relationships across them (i.e., the direction and magnitude of flow through the low-permeability unit)

Type 3: Permanent fresh-water/saline-water contacts. (Saline waters being defined as those waters with greater than 10,000 mg/l of Total Dissolved Solids).

The type of boundary separating ground-water units reflects the degree of interconnection between those units. Type 2 boundaries constitute a low degree of interconnection. A low degree is expected to be permanent unless improper management causes the low-permeability flow boundary to be breached. Type 1 and Type 3 boundaries imply an intermediate degree of interconnection. They are prone to alteration/modification due to changes in ground-water withdrawals and recharge.

A high degree of interconnection is inferred when the conditions for a lower degree of interconnection are not demonstrated. High interconnection of waters is assumed to occur within a given ground-water unit and where ground water discharges into adjacent surface waters. A high degree of interconnection implies a significant potential for cross-contamination of waters if a component part of these settings becomes polluted.

Class I - Special Ground Waters:

Class I ground waters are resources of unusually high value. They are highly vulnerable to contamination and are (1) irreplaceable sources of drinking water and/or (2) ecologically vital. Ground water, which is highly vulnerable to contamination, is characterized by a relatively high potential for contaminants to enter and/or to be transported within the ground-water flow system.

In these Draft Guidelines, the Agency is seeking comment on the appropriate approach to defining "highly vulnerable." Public comment will influence the Agency's choice of an approach for the Guidelines when they are issued in final form. To assist in framing the discussion, these Draft Guidelines focus on two options for determining vulnerability. Both of these require consideration of a number of hydrogeologic parameters. Option A would require use of the DRASTIC system (Aller et al, 1985), a numerical ranking system developed by the National Water Well Association under contract to EPA. The DRASTIC system provides a method of scoring an area's "vulnerability" based upon consideration of various parameters such as depth to water, recharge, aquifer media, etc. Using this approach, an area would be considered "highly vulnerable" if its DRASTIC score exceeds levels specified in these Guidelines. Option B does not rely on a set methodology with numerical criteria. Instead, vulnerability would be assessed in a more qualitative manner, relying on best professional judgement. The user might consider specific technical parameters within the DRASTIC system (i.e., depth to water, net recharge, aquifer media, etc.), but would not attribute scores to these parameters or provide numerical cutoffs for defining "highly vulnerable" areas. Other techniques would also be allowable under Option B. Thus, this alternative is considered qualitative in nature since specifics as to methods or criteria are not provided in these Classification Guidelines. Instead, the overall advantages and disadvantages of the general categories of techniques is provided. Comments on these two options, as well as other options for assessing vulnerability, will be considered by the Agency in determining how best to incorporate this factor in classification decisions.

Ground water may be considered "irreplaceable" if it serves a substantial population and if delivery of comparable quality and quantity of water from alternative sources in the area would be economically infeasible or precluded by institutional constraints.

In these Draft Guidelines, the Agency is also soliciting comment on approaches to judging two aspects of the "irreplaceable" criterion. Option A incorporates a quantitative determination of the population served by the source and the economic feasibility of replacing the source. Under this approach, a drinking water source would be considered "irreplaceable" if it serves at least 2500 people and the annual cost to a typical user of replacing the source exceeds 0.7 to 1.0 percent of the mean household income in the area. Option B focuses on a qualitative assessment of the replaceability of the ground water. Under this approach, the relative size of the population served by the source and the cost of replacing the source would be factors to consider in assessing the source's "replaceability." The Guidelines would not, under Option B, provide a set methodology, nor one or more numerical cutoffs. Again, the determination would focus on best professional judgement. A user following Option B may choose, however, to consider some of the quantitative methods or approaches in Option A, if deemed relevant in a particular classification decision. Comments on these two options, as well as other options for assessing "substantial population" and "irreplaceable" (from an economic standpoint), will be considered by the Agency in determining how best to incorporate these factors in classification decisions.

Ground water may be considered ecologically vital if it supplies a sensitive ecological system located in a groundwater discharge area that supports a unique habitat. A unique habitat is defined to include habitats for endangered or threatened species listed or proposed for listing pursuant to the Endangered Species Act (as amended in 1982), as well as certain types of Federally managed and protected lands.

Class II - Current and Potential Sources of Drinking Water and Water Having Other Beneficial Uses:

All non-Class I ground water currently used, or potentially available, for drinking water and other beneficial use is included in this category, whether or not it is particularly vulnerable to contamination. This class is divided into two subclasses; current sources of drinking water (Subclass IIA), and potential sources of drinking water (Subclass IIB).

Ground water is considered a current source of drinking water under two conditions. The first condition is the presence of one or more operating drinking-water wells (or springs) within the Classification Review Area. The second condition requires the presence within the Classification Review Area of a water-supply reservoir watershed (or portion of a water-supply reservoir watershed) designated for water-quality protection, by either state or local government.

The concept of a current source of drinking water is rather broad by intent. Only a portion of the ground water in the Classification Review Area needs to be supplying water to drinking-water wells.

A potential source of drinking water is one which is capable of yielding a quantity of drinking water to a well or spring sufficient for the needs of an average family. Drinking water is taken specifically as water with a total-dissolved-solids (TDS) concentration of less than 10,000 mg/l, which can be used without treatment, or which can be treated using methods reasonably employed in a public water-supply system. The sufficient yield criterion has been established at 150 gallons/day.

Class III - Ground Water Not a Potential Source of Drinking Water and of Limited Beneficial Use:

Ground waters that are saline, or otherwise contaminated beyond levels which would allow use for drinking or other beneficial purposes, are in this class. They include ground waters (1) with a total-dissolved-solids (TDS) concentration over 10,000 mg/l, or (2) that are so contaminated by naturally occurring conditions, or by the effects of broad-scale human activity (i.e., unrelated to a specific activity), that they cannot be cleaned up using treatment methods reasonably employed in public water-supply systems. Two alternative tests are proposed for making this determination. A reference-technology test is proposed in the draft and an optional economically-based test is included in Appendix G.

Class III is subcategorized primarily on the basis of the degree of interconnection with surface waters or adjacent ground-water units containing ground water of a higher class. Subclass IIIA ground waters have a high-to-intermediate degree of interconnection to adjacent ground-water units of a higher class or surface waters. In addition, Subclass IIIA encompasses ground waters in those settings where yields are insufficient from any depth within the Classification Review Area to meet the needs of an average size family. Such ground waters, therefore, are not potential sources of drinking water.

Subclass IIIB is restricted to ground waters characterized by a low degree of interconnection to adjacent surface waters or ground waters of a higher class within the Classification Review Area. These ground waters are naturally isolated from sources of drinking water in such a way that there is little potential for producing additional adverse effects on human health and the environment. They have low resource values outside of mining, oil and gas recovery, or waste disposal.

PART II

Classification Procedures

These Guidelines provide a more in-depth discussion of the actual process of site-by-site classification. The process is facilitated through a classification decision chart and associated worksheet. These were developed to provide a systematic approach to classifying ground water based on certain criteria, e.g., presence of wells, ecologically vital areas, water quality, irreplaceability, etc. They are provided as suggested approaches only, since a given setting may be more effectively handled through another sequence of steps.

Classification requires certain information on the character of the Classification Review Area. The emphasis of data collection is on readily available sources. More in-depth analyses are not expected routinely, but, may become necessary for Class I or, especially, Class III areas and for subdivision of the Classification Review Area.

Preliminary data needs include:

- Base map of the Classification Review Area,
- Inventory of public water-supply systems in the review area,
- Delineation of areas served by private wells,
- Demographic information for the public water-supply systems and areas of private wells,
- Survey of ecologically vital areas, and
- Hydrogeologic data sufficient to judge vulnerability of or support interconnection analysis.

The remaining sections of this chapter contain technical guidance for the following:

- Expansion of the Classification Review Area,
- Subdivision of the Classification Review Area and Determination of Interconnection,
- Determining Irreplaceability,
- Determining Ground-Water Vulnerability,
- Determination of Reasonable Treatment, and
- Ground-Water and Surface-Water Interactions.

PART III

The final chapters of this document are appendices which contain the following information:

Appendix A - Glossary

Appendix B - Alternative Options Considered

Appendix C - Sample Applications of Ground-Water Classification

Appendix D - DRASTIC Factors and Ratings

Appendix E - Background Data Regarding Class I and III

Appendix F - Census Bureau Information

Appendix G - Economic Tests for Determining Class I Irreplaceable Waters and Class III-Untreated Ground Waters

GUIDELINES FOR GROUND-WATER CLASSIFICATION
UNDER THE EPA GROUND-WATER PROTECTION STRATEGY

CONTENTS

TABLE OF CONTENTS (Cont.)

PART II
DETAILED CLASSIFICATION PROCEDURES

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

LIST OF FIGURES

LIST OF FIGURES (Cont.)

LIST OF TABLES

PART I

BACKGROUND AND DEFINITION OF GROUND WATER CLASSES

PART I

1.0 INTRODUCTION

1.1 EPA's Ground-Water Responsibilities

EPA currently administers more than eight statutes which direct the Agency toward reducing or eliminating threats to ground water from a large number and variety of sources. This is a far from simple task and is one which commands a major part of the Agency's budget and personnel resources. Changes in statutes and resulting regulations have occurred in the past, and will continue to occur in the future, to further manage these pollution sources. Through EPA's long-range planning efforts and, more recently, an agency-wide direction toward overall risk management, ground-water protection on a cross-media basis, the second "problem" is receiving increased attention.

An important tool in this cross-program phase was made available in August 1984, when EPA released its Ground-Water Protection Strategy. This Strategy represents the official policy of EPA in this field, and followed extensive debate and analysis within EPA, among other Federal and State agencies, and with the public. The goal of the Strategy is to maximize and coordinate protection functions, both within Headquarters and the Regions. It was not meant to resolve all of today's ground-water protection issues, but rather to set up a framework for better overall protection.

Ground-water classification was introduced in the Strategy as a key element in setting priorities for regulatory action prioritizing attention and resource management. As will be discussed more fully in Chapter 2.0, classification was deemed essential, given the potentially enormous numbers of pollution sources matched by the expense of clean-up programs, should contamination occur.

1.2 The Purpose of this Document

This document provides the technical guidelines for implementing the classification system, originally established in the Ground-Water Protection Strategy. By following the procedures and methods outlined, ground water, which may be affected by a facility or activity under EPA review, can be placed within a relevant class or classes, representing an implied hierarchy of protection. While the use of the system by EPA programs is discussed briefly in Section 2.3, this document should be viewed essentially as a set of technical guidelines for ground-water evaluation via classification.

Specific management strategies, "standards", and other program related policies, are outside the subject of this document.

It is also critical to note that EPA will not, as a result of these guidelines, the Strategy, or its current statutory authorities, be classifying large segments of land, aquifers, etc., in-advance of any specific decision. The Agency, or the delegated/authorized States, will only classify the ground water around specific sites or areas where a decision related to a permit, degree of clean-up or regulation, etc., is to be made. These differences are highlighted further in Chapter 2.0.

1.3 Organization of this Document

Chapter 2.0 provides additional background information on the Ground-Water Protection Strategy, including the rationale and use of classification. EPA's site-by-site approach is also contrasted with broader areawide mapping and classification efforts. The remainder of the guidelines document is organized into three major parts. Chapter 3.0 contains an overview of the classification system, and definitions and explanations of key terms and concepts. The procedures for classification are documented in Part II, Chapter 4.0. This chapter is designed for potential users of the system; whereas, the previous chapters provide less detailed information suited for general interest. Chapter 4.0 provides a step-by-step user's manual, covering the recommended sequence of decisions, corresponding data needs, and technical methods for each. A series of Appendices follows in Part III and includes a glossary (Appendix A) and a discussion of the alternative options considered for defining classification key terms and concepts (Appendix B). Appendix C is particularly relevant since it illustrates the classification procedures through a series of sample case studies. The remaining appendices provide background information and important references for performing the classification procedures.

2.0 BACKGROUND

2.1 Need for Ground-Water Classification

The EPA Ground-Water Protection Strategy (August, 1984) consists of four major elements:

- Strengthen State Institutions -- through technical assistance and State grants

- Cope with Unaddressed Sources -- through source-specific protection programs in cooperation with other EPA programs

- Establish EPA Policy for Ground-Water Protection-- through the establishment and implementation of protection policies

- Strengthen EPA Institutions -- through the establishment of Offices of Ground-Water Protection at Headquarters and in the Regions.

These guidelines stem from the third element, and the need to achieve greater consistency in the various programs at EPA with ground-water protection responsibilities. The Agency was concerned that the focus solely on individual polluting activities, rather than on the resource which might be affected, was leading to problems with consistency. Some EPA programs tended to factor-in ground-water considerations to a greater extent than other programs. Some EPA programs implemented specific statutes which themselves held a bias toward one medium, such as surface water, in a way that impacts on ground water were not fully assessed. Complicating the situation was the fact that many of these programs had become well established in their methods of operation.

In light of these factors, EPA adopted a policy for the Ground-Water Protection Strategy that "protection should consider the highest beneficial use to which ground water having significant water resources value can presently or potentially be put." This "differential protection" policy acknowledges that some ground water deserves unusually high protection due to their current use, relative value to society, and vulnerability to contamination. For these ground waters (Class I), management will include extra-ordinary protective measures. For most ground waters (Class II), the very high "baseline" of protection inherent in EPA's programs will be applied. Ground waters which have lower value to society for water supply or other disposal purposes (Class III), would logically, under this policy, require a different management approach. Furthermore, the policy asserts that the extremes of the system (i.e., Class I and III) should be restricted to rather infrequent situations, reflecting the importance of effectively managing ground water for its best use.

The Agency recognized that in-advance aquifer classification offers a community or State certain advantages from an overall management perspective. EPA believes, however, that such decisions should be made at the state or local levels of government. The major purpose of these guidelines is, however, to support the site-by-site assessments typically employed in EPA permits, impact statements, and other decisions. Differences among such systems are reviewed in Chapter 2.3.

The Ground-Water Protection Strategy established a more protective category (Class I) than had been in existence prior to 1984. This more protective category will be recognized in a consistent way from program to program. Class III provides for the formalization of where EPA programs can recognize lower resource values -- i.e., not sources of drinking water -- either now or in the foreseeable future.

2.2 Guidelines Development

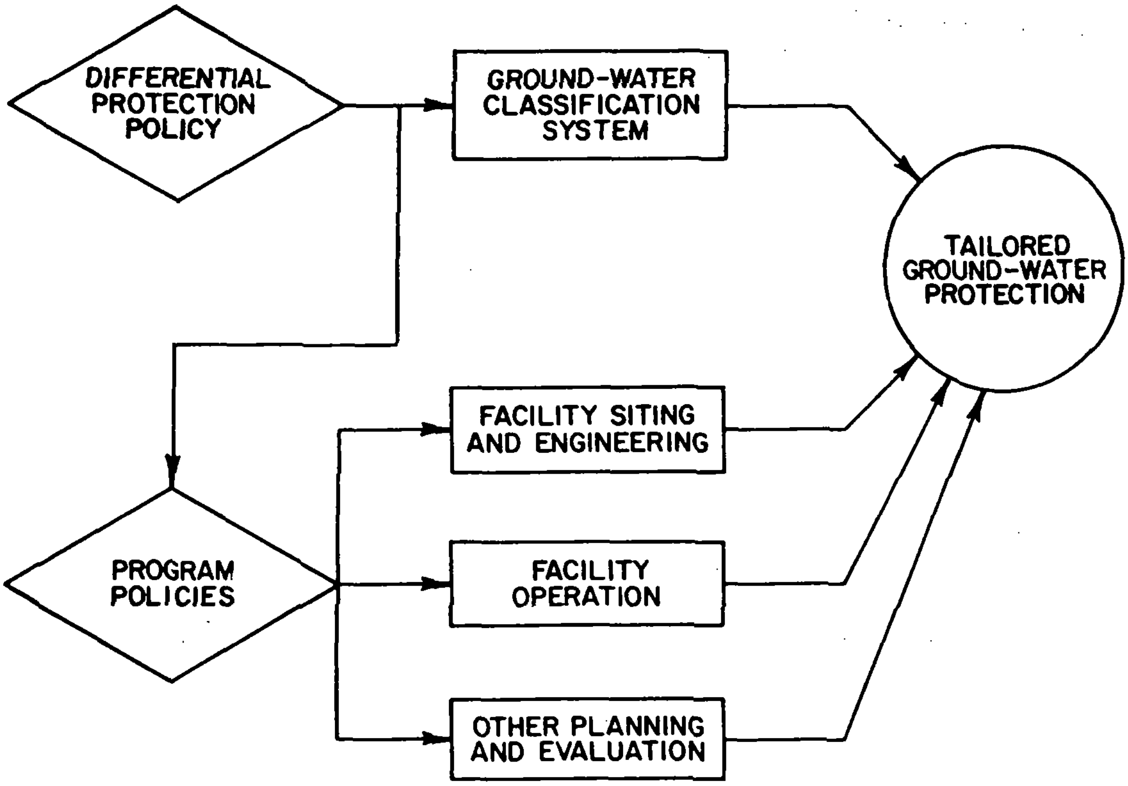
The development of these guidelines began in August, 1984, and consisted of three phases -- definition, testing, and review. Throughout the process, the Office of Ground-Water Protection (OGWP) worked closely with a guidelines work group, consisting of representatives from several states, EPA regions, other EPA programs, and the U.S. Geological Survey.

In the definition phase, key terms and concepts related to the classification scheme described in the Strategy were analyzed in detail. These included key terms and concepts such as "irreplaceable source of drinking water," "ecologically vital," "highly vulnerable," and "current source of drinking water." Several alternative options for defining each term were drawn up, along with data requirements and methodologies for employing each. Many of the alternative options were derived from approaches used by other EPA, state, and local programs to address similar or related concepts. Each approach was examined with respect to its:

- Consistency with statutes, other programs, and with the overall intent of the Strategy;

- Flexibility for accommodating State and region-specific characteristics or concerns;

FIGURE 2-1
CONCEPTUAL FRAMEWORK BETWEEN GROUND-WATER CLASSIFICATION AND PROGRAM POLICIES FOR FACILITY SITING, ENGINEERING, AND OPERATION



- Arbitrariness; and

- Potential difficulties or complexities in implementation.

The next phase involved the preparation of detailed case studies with which to test the initial classification framework. Candidate case studies were canvassed from a variety of sources and a small workshop held to determine the workability of the classification definitions and to select the most relevant and representative samples for the guidance document. The feedback from this phase led to a refinement of the classification system and procedures.

Finally, the project focused on review and revision of several drafts. The public will review and comment on this draft in late 1986. Comments from the public review will be factored into the development of final guidelines in 1987.

2.3 Implementation in EPA Programs

The Ground-Water Protection Strategy provides two key insights on implementation. First, the Strategy establishes the differential protection approach as an official Agency policy. Classification is set as the primary means to implement that policy. Next, the Strategy provides examples of how classification may be used by specific EPA programs to assist in framing various program policies. A conceptual schematic of this approach is shown in Figure 2-1.

In order to implement these classification guidelines (which are not themselves enforceable requirements), EPA programs will need to modify their specific guidance documents and regulations. Decisions as to how they are to be implemented can only be made through EPA program office actions, taking into consideration each program's statutory requirements. Actual implementation may be different than the examples portrayed in the Ground-Water Protection Strategy due to changes in statutes and the need to be consistent with more recent program policies. The approach cited for the Resource Conservation and Recovery Act (RCRA) program in the Strategy, for example, was presented in the framework that existed before the sweeping Hazardous and Solid Waste Act Amendments of 1984 (HSWA). As it responds to HSWA, EPA will develop a coherent approach to ground-water protection that incorporates such Congressionally-mandated requirements under HSWA as the waste-specific "waste bans," location guidance/standards, liner/technology standards, and corrective action requirements. Differential protection and classification will also be incorporated into this broader context.

Two specific rule-making actions have been completed--one for Superfund, and one under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, or "Superfund"), and one for radioactive wastes. The CERCLA National Contingency Plan (NCP) revised on November 20, 1985 (50 FR 47974) establishes the process for removal and/or remedial actions at Superfund sites (40 CFR Part 300). Revised Section 300.68(e)(2) addressing scoping of response actions during remedial investigations includes an assessment of "(v) Current and potential ground-water use (e.g., the appropriate ground-water classes under the system established in the EPA Ground-Water Protection Strategy" to assist in the determination of what type of action should be taken.

EPA also cites the Strategy in its list of other Federal criteria, advisories, guidance, and State standards to be considered. The list is found in the October 2, 1985, policy on CERCLA compliance with other Environmental Statutes (published as an appendix to the preamble of the NCP). The policy provides that (among other things) the classification factors must be considered in remedial action if it is pertinent. If the Agency finds that they are pertinent in response actions, but does not use them, or uses and alters them, the decision documents must state the rationale. Guidance manuals for implementing the new NCP are under development by the Agency.

The second completed implementation action is the release of the "Environmental Standards for the Management of Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes." EPA's role under the overriding Atomic Energy Act is very limited and is primarily standard-setting. The final rule (40 CFR Part 191; released in the Federal Register on September 19, 1985) includes two standards relative to differential protection:

- A drinking-water-related standard is to be applied to all locations if a "special source" of ground-water is present. "Special sources" are further defined as a major subset within the Class I definition included in these guidelines.

- A "total dose"-related standard is to be applied at the boundary of a "controlled area" for "significant sources of ground water." "Significant" sources are essentially a major subset within the Class II definition included in these guidelines.

At this time, conceptual approaches to implementation are in different stages of development and consideration by programs administering all major ground-water related statutes in EPA. In permit-based, "point-source"-type actions, it is expected that classification will be essentially an additional step in site-specific analysis. Broader-based, non permit/non-point sources are more problematic. In farm-by-farm application of pesticides, for example, there is no regulatory mechanism to evaluate each site-by-site action. EPA is beginning to consider the approaches to implementing differential protection and other Strategy-related policies for these broader sources. Again, the classification guidelines will be implemented as appropriate, given the overall authorities of the Agency under specific statutes.

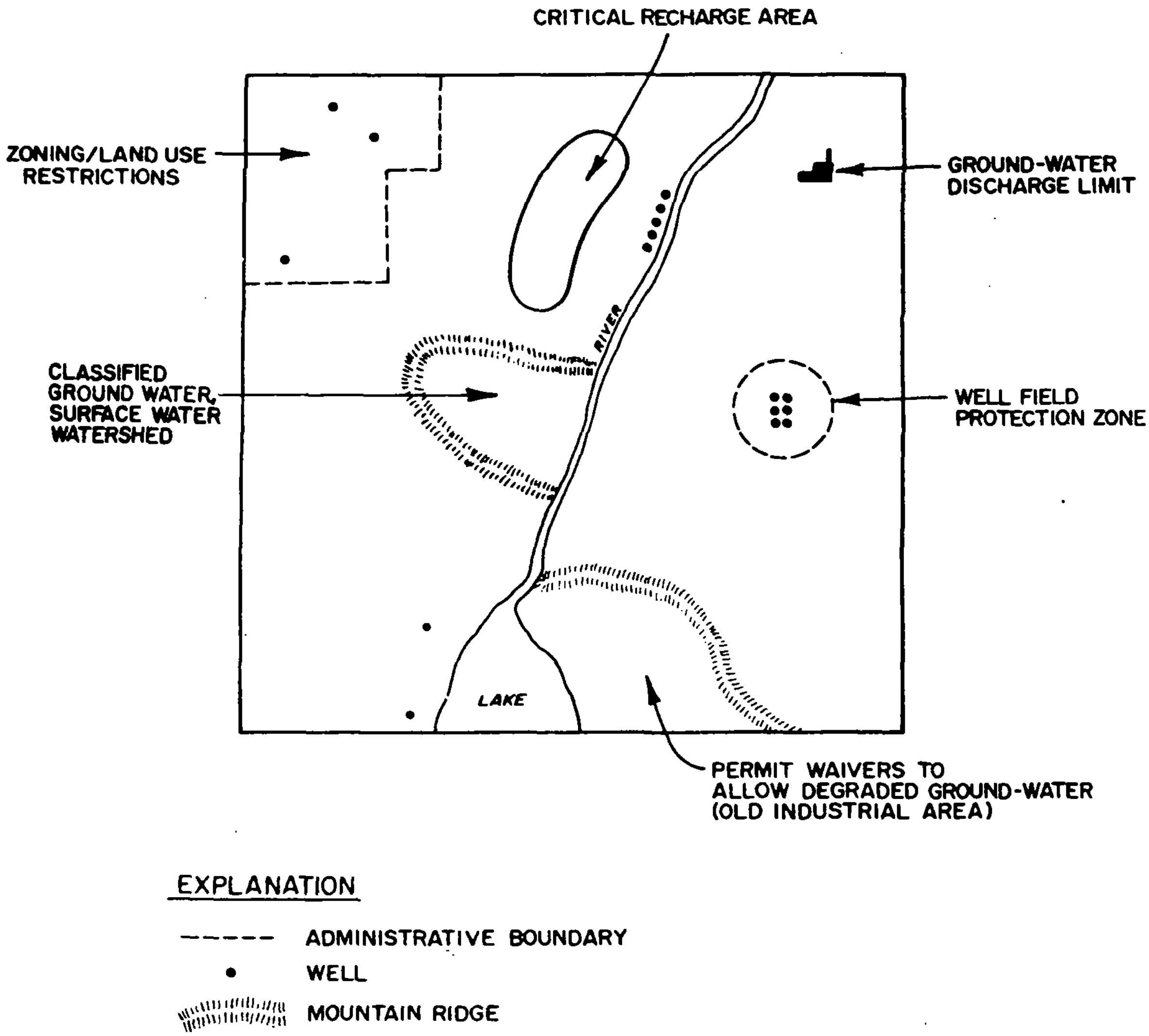
Since neither the guidelines definitions nor the program implementation options have been finalized, it is impossible to predict the numbers of EPA classification decisions which will result or be included in each particular class. Some initial analyses have been performed utilizing aggregated (i.e., not site specific) data on gross hydrogeological and socioeconomic characteristics around a subset of over 1400 RCRA, CERCLA, and UIC facilities. Assuming that the "quantitative" options (all denoted as Option A in Section 3.0 and 4.0) are selected, the range in classification outcomes covers:

Class I	5 to 11 percent
Class II	83 to 94 percent
Class III	1 to 6 percent

Given the different interpretation of the "qualitative options" for Class I terms (each denoted as Option B), no such analyses could be performed. It is important to note, however, that these estimates reflect the percentage of classification decisions and not percentage of all United States ground water or aquifers. Additionally, these estimates were made on the basis of several assumptions regarding individual site characteristics. Sensitivity analyses show that the above ranges in percentage values account for most of the uncertainties associated with these assumptions.

It is appropriate to note, however, that well-field protection is typically the "high end" of any classification system as it is most often oriented to current, important public water supplies. Potential drinking water sources, ecologically vital ground waters, and low-quality, non-drinking water sources are not identified or managed in such systems.

FIGURE 2-2
EXAMPLE OF STATE PROTECTION SYSTEMS



A final note: these guidelines may not be used as a defense or guide to future settlements of Federal enforcement or other administrative or judicial cases unless, or until, specific programs issue implementing directives, regulations, or policies on how these concepts are to be applied to specific programs in a consistent manner with their statutory authorities and mandates.

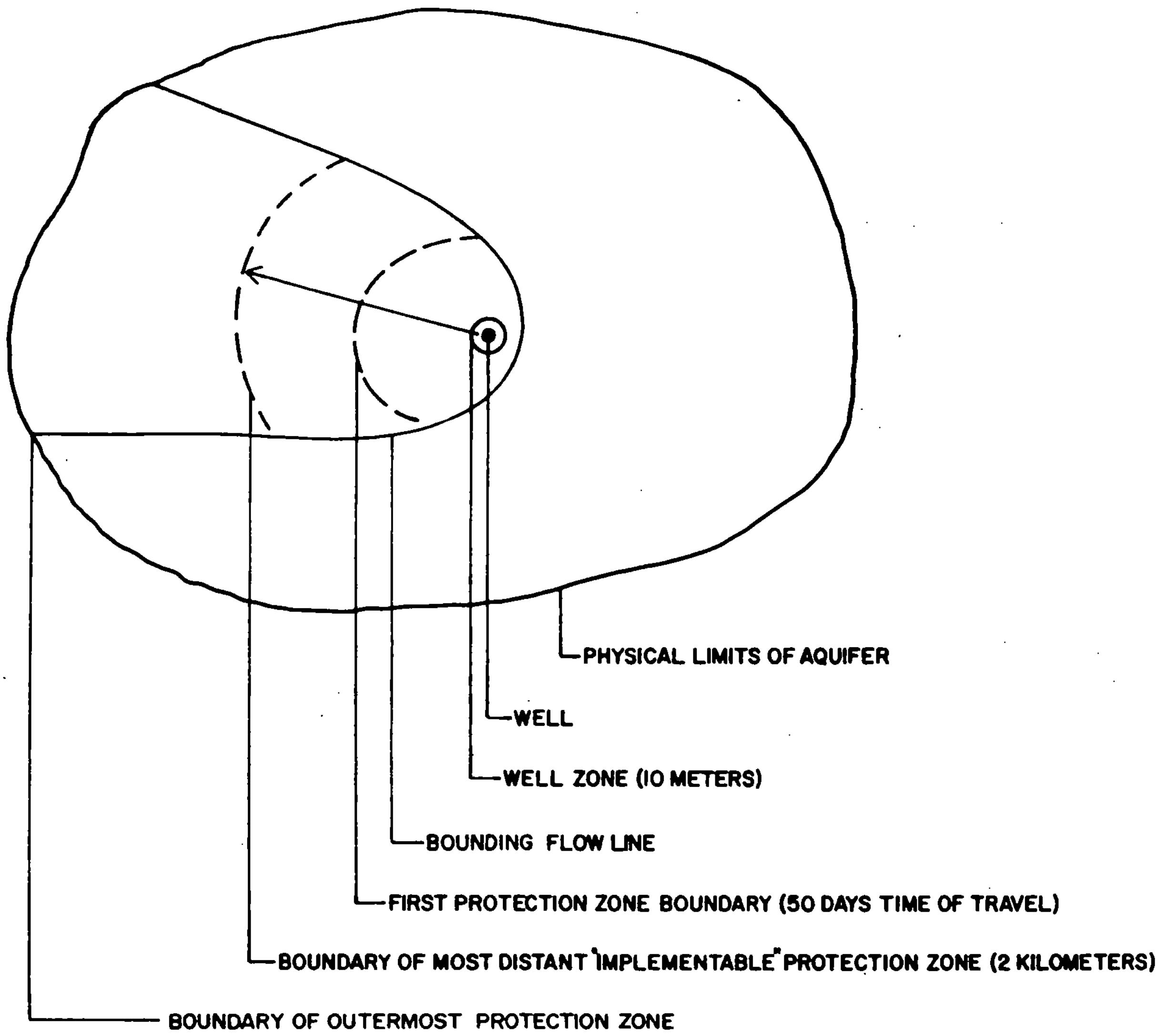
2.4 Interaction with State Ground-Water Protection Efforts

The EPA Ground-Water Classification system will be used as an important tool for decision-making in EPA programs, including those programs delegated to the states. State agencies responsible for ground-water management will not be required to adopt the EPA classification system or another system for general state program use. State agencies implementing delegated or authorized EPA programs will, however, need to use these classification guidelines as appropriate to those programs. Many states have, however, developed ground-water protection approaches that are tailored to their particular land use and hydrogeologic conditions (e.g. generic examples in Figure 2-2). At this time, at least half of the States have in operation, or under serious consideration, some form of site-by-site or in-advance classification system.

It is important to distinguish between these two generic types of classification systems. An in-advance or anticipatory approach to hydrogeologic mapping or aquifer classification is believed by many to be essential for effective local ground-water management (e.g., Conservation Foundation 1985). Through this process, geologic and hydrologic characteristics of currently used or potentially available ground-water sources are assessed through mapping, computer simulation, etc. Plans for water use are drawn-up, and land-use controls either suggested and/or actually put into place. These controls may be fairly sweeping in nature and cover industrial siting, housing development, road construction, etc.

Several Western European countries implement the concept of well-field protection zones (Figure 2-3), often thought of as the most pragmatic approach to anticipatory classification of public water-supply settings (e.g., Milde, et al, 1983). In West Germany, for example, nearly 80 percent of the 14,000 well fields in that country have protection areas in-place or in the process of being established. The key protection area is located within 2 kilometers (about 1.2 miles) from the well. As in most such systems, only a portion of the entire

FIGURE 2-3
IDEALIZED WELL FIELD PROTECTION ZONES IN WEST GERMANY
(AFTER MILDE ET. AL., 1983)



aquifer is given the "special" designation. In Switzerland the distances are shorter (minimum of 200 meters or about 650 feet); those in the Netherlands are time-of-travel based (typically 10 and 25 years travel time). Well-field protection zones are incorporated in some state and local protection systems; most notably, in Florida and the New England states.

There has been considerable activity at the Federal level in the area of enhancing State protection efforts. On June 19, 1986, the President signed into law the Safe Drinking Water Act Amendments of 1986. This law includes two new ground-water provisions, the first of which, (Section 1427), is a demonstration program establishing critical aquifer protection areas (CAPA) within Sole Source Aquifers. This is considered a program which is limited in extent, and geared to demonstrating techniques for protection of certain important ground waters.

The second element of the Amendments requires the States to develop programs to protect the wellhead areas of all public water systems within their jurisdiction "from contaminants that may have any adverse effects on the health of persons." These wellhead protection areas are defined as "any surface or subsurface areas surrounding wellfields through which contaminants are reasonably likely to move and reach a well or wellfield." EPA is required to issue technical guidance within a year after enactment which the States <u>may</u> use (i.e., may <u>not</u> choose to use) for determining the extent of the wellhead protection areas.

The Act specifies that the following elements be incorporated into State programs:

- Duties of State and local agencies and public water supply systems in implementing the program

- Determination of wellhead protection areas for each public well

- Inventory of all potential anthropogenic sources within the protection area

- A program that contains as appropriate, technical assistance, financial assistance, implementation of control measures, education training and demonstration projects to protect the wellhead areas from contaminants

- Contingency plans for alternative water supplies in case of contamination

- Siting considerations for all new wells

- Procedures for public participation.

This program must be submitted to the Administrator of EPA within the three years after enactment and the States are expected to implement this program within two years after it has been approved by the Administrator. The only effect on a State of failing to submit a Wellhead Protection Program, however, is the loss of related funds.

The provision is structured to give all States maximum flexibility in formulating their programs and the Administrator will disapprove a program only if it is not adequate to protect public water wells from contamination. Any disapproval must be made within nine months of submittal; and, should a program be disapproved, a State must modify the program and resubmit their plans within six months.

Once a program is approved, the Administrator shall make 50 to 90 percent match grants to the State for costs for the development and implementation of the State program. The Congress has authorized $20 million for each of FY 1987 and 1988 and $35 million for each FY 1989 through 1991. As of this date, however, no funds for FY 1987 have been appropriated.

It is appropriate to note, however, that wellfield protection is typically the "high end" of any classification system, as it is most often oriented to current, important public water supplies. Potential drinking water sources, ecologically vital ground waters, and low-quality, non-drinking water sources are not identified or managed in such systems.

The important point is that anticipatory classification is best performed and implemented by State and local governments that hold land-use authority. Under its program, existing statutes and budget resources, EPA can only perform site-by-site classification as part of its routine program-by-program effort. The classification system outlined in this guidelines document attempts to be generally consistent with broader anticipatory classification systems. Unlike anticipatory classification, which takes many years (and considerable technical and financial resources) to implement, site-by-site classification can be rapidly factored into EPA procedures in a way that is legally consistent with Agency authorities. By taking this approach, however, EPA does not wish to discourage anticipatory classification -- an approach which the Agency feels is a very useful one for effective resource management at the State and local levels.

Since a cornerstone of the Ground-Water Protection Strategy is fostering State-specific efforts, EPA is considering the substitution of State ground-water classification systems for the EPA system wherever possible. Given past program precedents, the State system will most likely need to be "equivalent to" or "at least as stringent" as EPA's. Since the implementation of the EPA ground-water classification system is still in the early stages, specific criteria or factors for such evaluations have not been determined. Options for Agency consideration, even though preliminary in nature, will be examined over the course of the next year. Institutional mechanisms at the Headquarters and Regional levels for reviewing such systems will also be considered.

In addition, EPA will be evaluating the legal basis for incorporating State Wellhead Protection areas approved by the Agency under the SDWA Amendments into its operating programs, as well as into this ground-water classification framework.

3.0 THE EPA GROUND-WATER CLASSIFICATION SYSTEM

The EPA Ground-Water Protection Strategy established three general classes of ground water representing a hierarchy of ground-water resource values to society. These classes are:

- Class I - Special ground water
- Class II - Ground water currently and potentially a source for drinking water
- Class III - Ground water not a source of drinking water.

The classification system is, in general, based on drinking water as the highest beneficial use of the resource. Ground water does serve other beneficial uses, such as manufacturing, electric power generation, livestock production, irrigation, and ecosystem support. Most such uses of ground water will be encompassed in Class I or Class II, in that water of a quality suitable for drinking will also be of a quality to serve as a raw water source for most other beneficial uses. Class I does include a special non-drinking-water component for "ecologically vital" ground water. A more complete discussion of the other beneficial uses of ground water is found in Appendix B.

The classification system is designed to be used in conjunction with the site-by-site assessments typically conducted by the EPA program offices in issuing permits, deciding on appropriate corrective action, etc. The Agency does not have authority within its statutes to require states to do broad-scale, in-advance (anticipatory) aquifer mapping or classification. Those states which do choose to adopt such tools will, of course, have a key component for comprehensive resource management. Anticipatory classification of aquifers is one of the ten components of a state comprehensive ground-water protection program recommended by the National Ground-Water Policy Form (Conservation Foundation, 1985).

The EPA Ground-Water Classification system allows EPA to incorporate many of the same concepts found in state systems into the Agency's routine case-by-case decision making. An important surrogate for in-advance mapping employed in the EPA system is the Classification Review Area. This is the area or, in actual terms, the volume to which the classification criteria primarily apply and is explained more thoroughly in Section 3.2.

The remaining discussion in this section focuses on defining the classes and key terms and concepts of the EPA Ground-Water Classification System. Many technical terms are used in the descriptions, a number of which are defined in the Glossary (Appendix A).

The class definitions presented in this document have evolved from those presented in the Ground-Water Protection Strategy. While there are no substantive changes in the class concepts, the descriptions are revised to reflect the results of the guidelines development process. For this reason, the reader should reference those parts of the Strategy document defining the classification system primarily for background purposes.

Finally, it should be noted that the Agency is requesting public comment on all these terms and definitions. Particular attention should be placed on the approach to defining three Class I terms: "highly vulnerable," "substantial population," and "economically infeasible." Whereas only one option is presented for the bulk of the classification terms, two options are presented for each of these three Class I defining terms.

3.1 An Overview of the Ground-Water Classes and Subclasses

The EPA Ground-Water Classification System consists of three major classes. Two classes are subdivided into subclasses, allowing for the refinement in the hierarchy of recognized resource values (Figure 3-1). The classes and subclasses of ground water are differentiated using key terms and concepts. The relationship between classes and key terms is illustrated in Figure 3-2 and flow-charted conceptually in Figure 3-3.

3.1.1 Class I - Special Ground Waters

Class I ground waters are resources of unusually high value. They are highly vulnerable to contamination and are (1) irreplaceable sources of drinking water and/or (2) ecologically vital. Ground water may be considered "irreplaceable" if it serves a substantial population, and, if delivery of comparable quality and quantity of water from alternative sources in the area would be economically infeasible or precluded by institutional constraints. (It should be noted that the Agency is providing several options for determining these factors, so as to focus public comment on the best way of incorporating these concerns in classification decisions.) Ground water may be considered "ecologic-

FIGURE 3-1
SUMMARY OF GROUND-WATER CLASSES

CLASS	KEY TERMS	EXAMPLE MANAGEMENT*
I	HIGHLY VULNERABLE AND EITHER IRREPLACEABLE TO SUBSTANTIAL POPULATIONS <u>OR</u> ECOLOGICALLY VITAL	MOST RESTRICTIVE
IIA	CURRENT SOURCE OF DRINKING WATER	
		BASELINE
IIB	POTENTIAL SOURCE OF DRINKING WATER	
IIIA	NOT A SOURCE OF DRINKING WATER INTERMEDIATE TO HIGH INTERCONNECTION AND >10,000 MG/L TDS <u>OR</u> UNTREATABLE <u>OR</u> NOT A SOURCE OF DRINKING WATER DUE TO INSUFFICIENT YIELD	LEAST RESTRICTIVE
IIIB	NOT A SOURCE OF DRINKING WATER LOW INTERCONNECTION >10,000 MG/L TDS OR UNTREATABLE	

*Management approaches will be developed on a program-specific basis in EPA.

FIGURE 3-2
RELATIONSHIP OF CLASSES, KEY TERMS, AND CONCEPTS

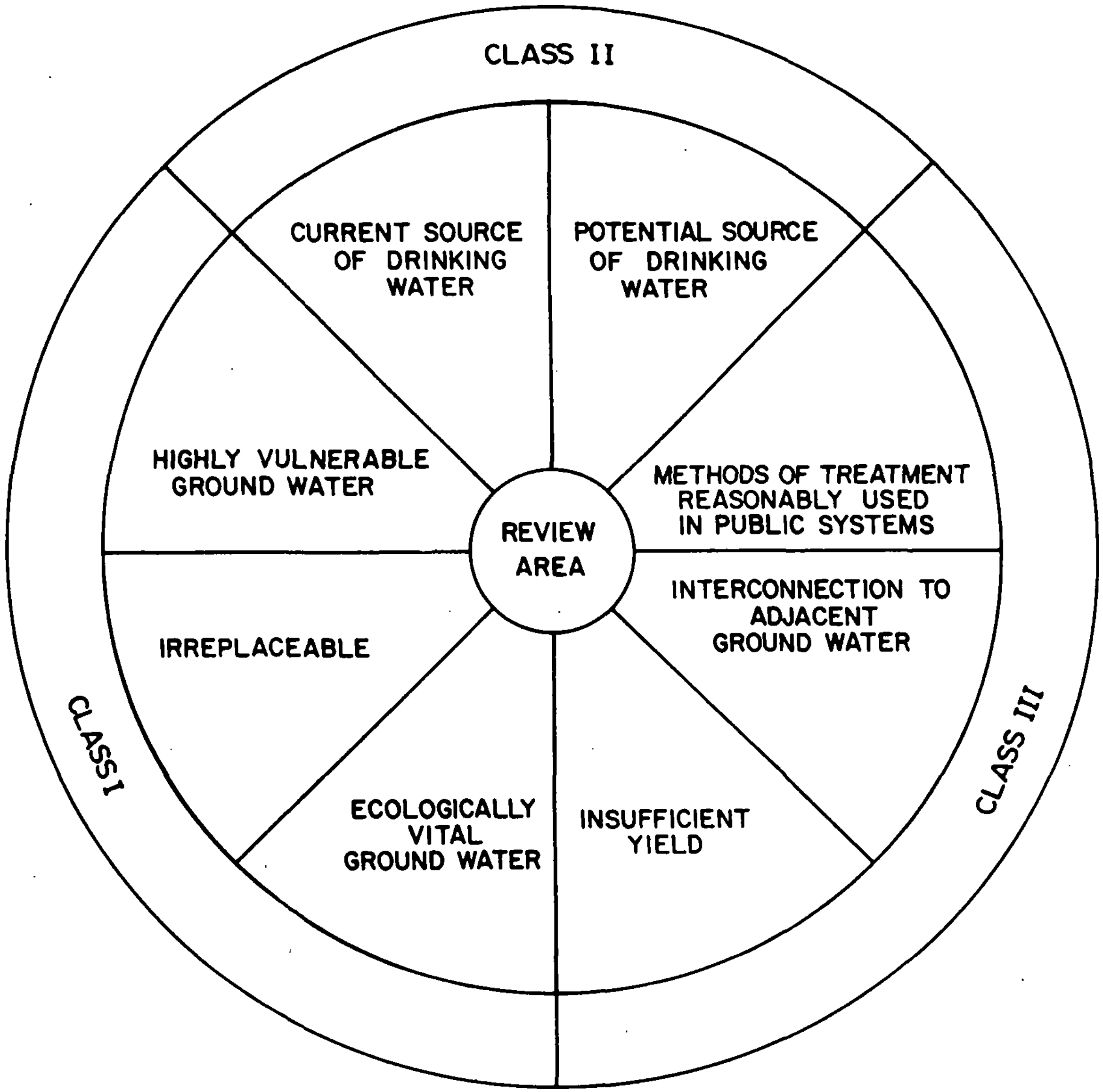
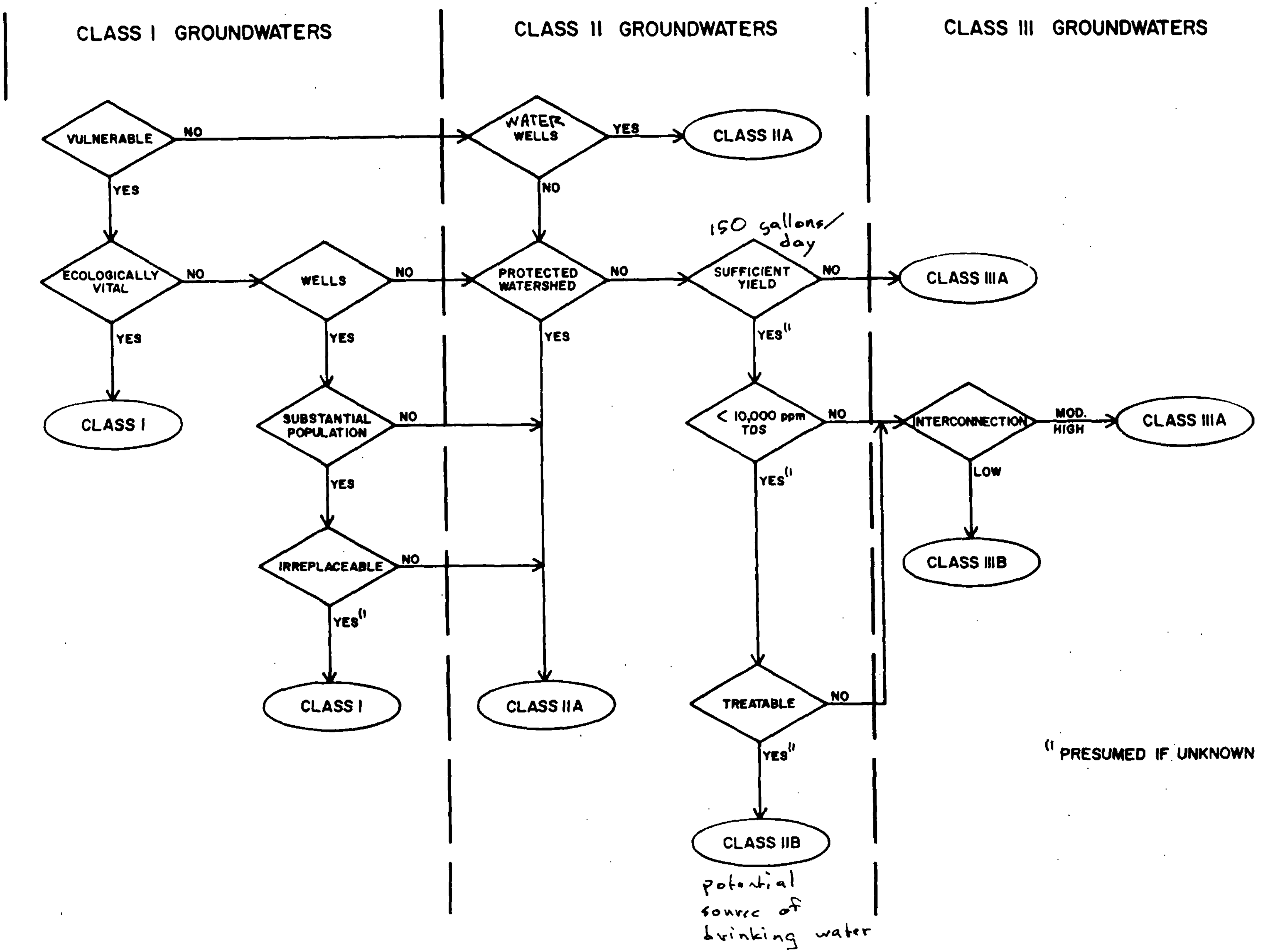


FIGURE 3-3
CONCEPTUAL CLASSIFICATION FLOW CHART



ally vital" if it supplies a sensitive ecological system that supports a unique habitat.

It should be noted that a site located in a designated Safe Drinking Water Act Sole Source Aquifer (SSA) is not automatically placed in Class I. The criteria for SSAs are less rigorous than those of Class I. Greater rigor is needed for classification since, unlike SSAs, Class I will be a decision-making factor in program regulations. SSAs are only considered at the Federal level under financially assisted projects such as farm loans, rural water districts, etc.

It is expected that Class I decisions will be small in number. Such ground waters will generally receive extraordinary protection due to the potential risk to large numbers of citizens dependent upon a source of drinking water or the risk of further endangerment to endangered or threatened species dependent upon unique habitats.

The key terms and concepts used to distinguish Class I include:

- highly vulnerable to contamination
- ecologically vital ground water
- irreplaceable source of drinking water
  - substantial population
  - comparable quality
  - comparable quantity
  - institutional constraints
  - economic infeasibility.

3.1.2 Class II - Current and Potential Sources of Drinking Water and Water Having Other Beneficial Uses

All non-Class I ground water currently used, or potentially available, for drinking water and other beneficial use is included in Class II, whether or not it is particularly vulnerable to contamination. This class is divided into two subclasses; current sources of drinking water (Subclass IIA), and potential sources of drinking water (Subclass IIB).

Class II ground waters comprise the majority of the nation's ground-water resources that may be affected by human activity. Class II ground waters will generally receive the very high level of protection which represents the "baseline" of EPA programs. It is assumed that any ground water which is currently used for drinking water will fall in Subclass IIA, unless Class I criteria apply. Other ground waters are considered potentially usable as a source of drinking water, both from quality and yield standpoints (Subclass IIB), until demonstrated otherwise.

3.1.3 Class III - Ground Water Not a Potential Source of Drinking Water and of Limited Beneficial Use

Ground waters that are saline, or otherwise contaminated beyond levels which would allow use for drinking or other beneficial purposes, are in this class. They include ground waters (1) with a total dissolved solids (TDS) concentration over 10,000 mg/l, or (2) that are so contaminated by naturally occurring conditions, or by the effects of broad-scale human activity (i.e., unrelated to a specific activity), that they cannot be cleaned up using treatment methods reasonably employed in public water-supply systems.

Class III ground-water units* are subcategorized primarily on the basis of their degree of interconnection with surface waters or adjacent ground-water units of a higher class. In addition, Class III encompasses ground waters in those very rare settings where yields are insufficient from any depth within the Classification Review Area to meet the needs of an average size family. Such ground waters, therefore, are not potential sources of drinking water.

The key terms and concepts used to evaluate a Class III decision include:

- interconnection to adjacent ground-water units (as defined in Section 3.3) and surface waters
- treatment methods reasonably employed in public water supply systems
- insufficient yield.

Subclass IIIA includes ground-water units which are highly to intermediately interconnected to adjacent ground-water units of a higher class and/or surface waters. These may, as a result, be contributing to the degradation of the adjacent waters. They may be managed at a similar level as Class II ground waters depending upon the potential for producing adverse effects on the quality of adjacent waters.

The subdivision of Class III represents a refinement in the classification system as originally presented in the Ground-Water Protection Strategy. Placing shallower, more interconnected, ground waters in Class II, for example, would

*The concept of ground-water units is discussed in Section 3.3.

imply a quality and resource value that may not be appropriate. The Class IIIA designation in these cases provides a clear indication that these highly interconnected ground waters are not in themselves sources of drinking water.

Class IIIB is restricted to ground-units characterized by a low degree of interconnection to adjacent surface-waters or other ground-water units of a higher class within the Classification Review Area. These ground waters are naturally isolated from sources of drinking water in such a way that there is little potential for producing adverse effects on quality. They have low resource values outside of mining or waste disposal.

3.2 Classification Review Area

Classifying ground water necessitates delineating a segment of ground water to which the classification criteria apply. Since EPA is not classifying ground water on a regional or aquifer-specific basis, an alternative to defined aquifer segments is needed. This is the Classification Review Area.

It is important to understand that the Classification Review Area is delineated as part of the site-by-site review process. It is a review area and not a regulatory area. To put it another way, EPA believes it appropriate to look at a broad area for characterizing the types of ground water of concern. Regulatory or permit controls will not be imposed in that entire area; only that particular portion or site which is subject to the EPA program which is utilizing the classification for decision making.

The Classification Review Area is delineated based initially on a two-mile radius from the boundaries of the "facility" or the "activity." The facility or activity may be physical in nature (e.g., the edge of proposed surface impoundment) or hydrogeologic (e.g., the edge of contamination area). The dimensions of the Classification Review Area can be expanded in hydrogeologic settings of intermediate to very high ground-water flow velocities where these velocities occur over distances greater than two miles. A detailed discussion of these settings and procedures to expand the review are provided in Part II, Section 4.2.

Within the Classification Review Area, a preliminary inventory of public supply wells, populated areas not served by public supply, wetlands, and surface waters, is performed as described in Part II, Section 4.1. The classification criteria are then applied to the Classification Review Area and a classification determination made.

Initially, all ground water within the Classification Review Area is assumed to be highly connected hydrogeologically to the activity (both vertically and horizontally). This approach will always lead to the highest class determination. Where more hydrogeologic data are available, the Classification Review Area can be subdivided to reflect a more accurate appraisal of the interconnection between the ground waters associated with the activity and other ground waters of the Classification Review Area. This topic is presented in the following section (3.3). Where the Classification Review Area is subdivided, a decision resulting in several ground-water classes could result. For example, a disposal well could potentially affect all ground water through which the well is constructed. If the disposal well penetrates a fresh water zone in order to inject into a deeper, salt water zone, a classification decision for both zones would be needed.

Figure 3-4 illustrates a Classification Review Area around a proposed facility. The site of the facility is approximately 500 feet in diameter. Water supplies in the Classification Review Area include a public water supply system well and a densely settled area of private wells. A river with a wetland runs through the review area. Each of these facts may bear on the decision of the class of ground water.

3.2.1 Technical Basis for Two-Mile Radius

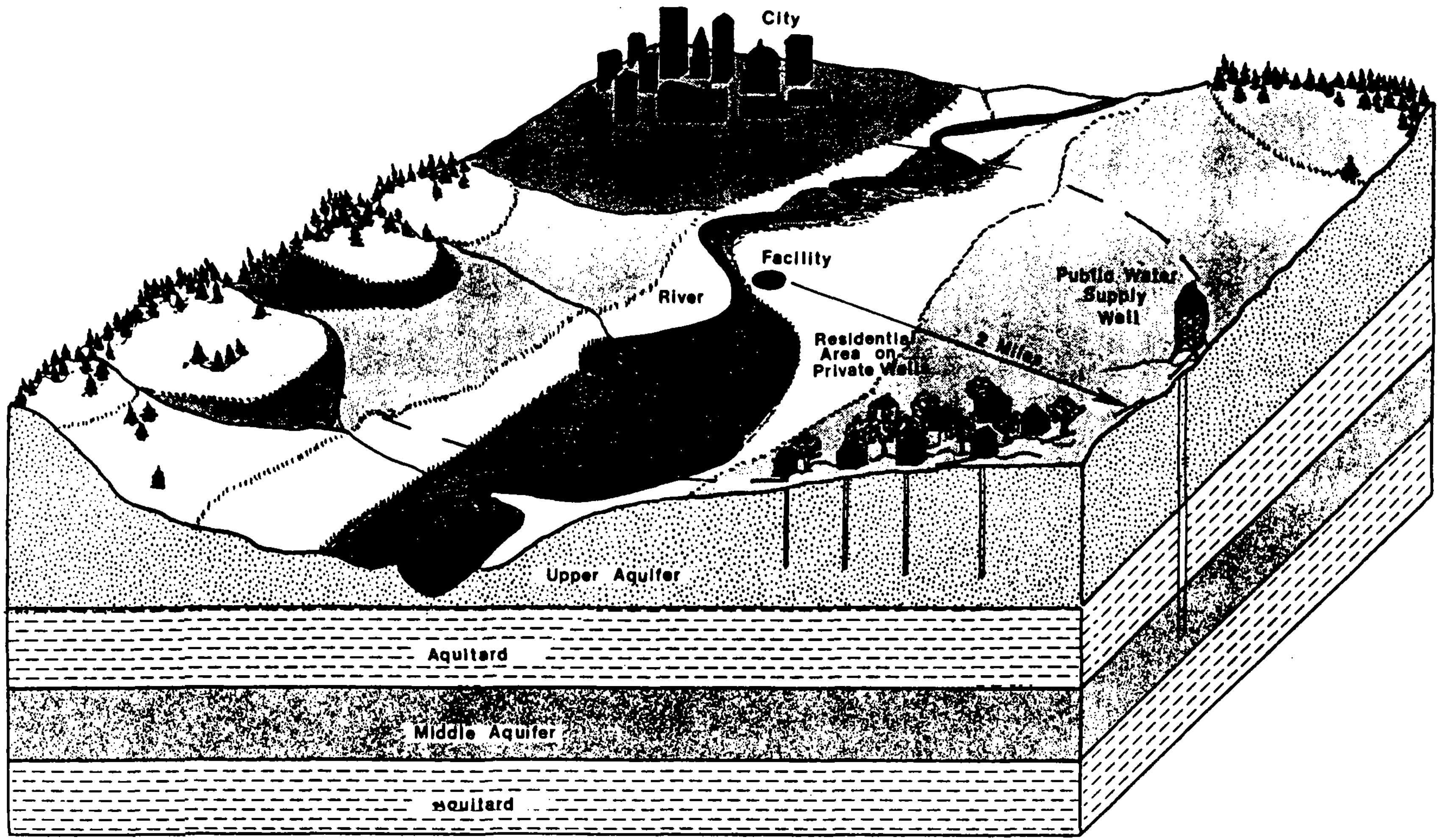
EPA examined three sources of data in establishing the radius of the Classification Review Area. The data provided insight into the length of flow path over which high degrees of interconnection occur. In addition, they indicate distances contaminants could be expected to move in problem concentrations should they be accidentally introduced into the ground-water system. The data sources were:

- A survey of contaminant plumes from investigations of existing spills, leaks, and discharges

- A survey of the distances to downgradient surface waters from hazardous-waste facilities

- Calculations of the distances from which pumping wells draw ground water under different hydrogeologic settings.

FIGURE 3-4
HYPOTHETICAL CLASSIFICATION REVIEW AREA SHOWING POTENTIAL CLASS DETERMINING FACTORS



A discussion of this data and its interpretation is provided in Appendix E.

3.3 Subdivision of the Classification Review Area: Concepts of Ground-Water Units and Interconnection

Subdivision of the Classification Review Area is allowed in order to recognize naturally occurring ground-water bodies that may have significantly different use and value. For purposes of subdividing the review area, these ground-water bodies, referred to as "ground-water units", must be characterized by a degree of interconnection (between adjacent ground-water units) such that an adverse change in water quality to one ground-water unit will have little likelihood of causing an adverse change in water quality in the adjacent ground-water unit. Each ground-water unit can be treated as a separate subdivision of the Classification Review Area. A classification decision is made only for the ground-water unit or units potentially impacted by the activity.

The concepts of ground-water units and the interconnection between adjacent ground-water units are particularly important to the application of the classification system. First, the degree of interconnection to adjacent ground-water units and surface waters is a criterion for differentiating between subclasses of Class III ground waters. Second, the delineation of ground-water units establishes a spatial limit for classification and the application of protective management practices. Hydrogeologists routinely assess the interconnection between bodies of ground water for such purposes as designing water-supply systems, monitoring systems, and corrective actions of contaminated water. Where ground-water bodies are shown to be poorly interconnected, it is possible to spatially distinguish between their use and value. Waters within a ground-water unit are inferred to be highly interconnected and, therefore, a common use and value can be determined. As a consequence, it is possible to selectively assign levels of protection to specific ground-water units to reflect differences in use and value. Protection applied to adjacent ground-water units will have little beneficial effects.

The identification of ground-water units and the evaluation of interconnection between ground-water units may, in critical cases, require a rigorous hydrogeologic analysis. The analysis may be dependent upon data collected off site that is not part of the readily available information normally used in a classification decision. For these reasons, the acceptance of subdivisions will be on a case-by-case basis after review of the supporting analysis. A discussion of appropriate analyses is presented in Part II, Chapter 4.0.

3.3.1 Ground-Water Units

Ground-water units are components of the ground-water regime, which is defined as the sum total of all ground water and surrounding geologic media (e.g., sediment and rocks). The top of the ground-water regime would be the water table; while, the bottom would be the base of significant ground-water circulation. Temporarily perched water tables within the vadose zone (see Glossary) would generally not qualify as the upper boundary of the regime. The Agency recognizes that upper and lower boundaries are sometimes difficult to define and must be based on the best available information and professional judgment.

The ground-water regime can be subdivided into mappable, three-dimensional, ground-water units. These are defined as bodies of ground water that are delineated on the basis of three types of boundaries as described below:

Type 1: Permanent ground-water flow divides. These flow divides should be stable under all reasonably foreseeable conditions, including planned manipulation of the ground-water regime.

Type 2: Extensive, low-permeability (non-aquifer) geologic units (e.g., thick, laterally extensive confining beds), especially where characterized by favorable hydraulic head relationships across them (i.e., the direction and magnitude of flow through the low-permeability unit). The most favorable hydraulic head relationship is where flow is toward the ground-water unit to be classified and the magnitude of the head difference (hydraulic gradient) is sufficient to maintain this direction of flow under all foreseeable conditions. The integrity of the low-permeability unit should not be interrupted by improperly constructed or abandoned wells, extensive, interconnected fractures, mine tunnels, or other apertures.

Type 3: Permanent fresh water-saline water contacts (saline waters being defined as those waters with greater than 10,000 mg/l of Total Dissolved Solids). These contacts should be stable under all reasonably foreseeable conditions, including planned manipulation of the ground-water system.

3.3.2 Interconnection

The type of boundary separating ground-water units reflects the degree of interconnection between those units. Adjacent ground-water units demarcated on the basis of boundary Type 2 are considered to have a low degree of interconnection. A low degree of interconnection implies a low potential for adverse changes in water quality within a ground-water unit due to migration of contaminated waters from an adjacent ground-water unit. A low degree of interconnection is expected to be permanent, unless improper management causes the low-permeability flow boundary to be breached. The lowest degree of interconnection occurs where a Type 2 boundary separates naturally saline waters from overlying fresh waters (less than 10,000 mg/l TDS), and the hydraulic gradient (flow direction) across the boundary is toward the saline waters.

Adjacent ground-water units demarcated on the basis of boundary Type 1 and 3 are considered to have an intermediate degree of interconnection. An intermediate degree of interconnection also implies a relatively low potential for adverse changes in water quality within a ground-water unit due to migration of contaminated waters from an adjacent ground-water unit. Type 3 boundaries, however, are characterized by a diffusion zone of fresh water-saline water mixing that will be affected by changes in water quality in either of the adjacent ground-water units. Type 2 and 3 boundaries are also prone to alteration/modification due to changes in ground-water withdrawals and recharge.

A high degree of interconnection is inferred when the conditions for a lower degree of interconnection are not demonstrated. High interconnection of waters is assumed to occur within a given ground-water unit and where ground water discharges into adjacent surface waters. A high degree of interconnection implies a significant potential for cross-contamination of waters if a component part of these settings becomes polluted.

3.3.3 Illustration of a Subdivision

The Classification Review Area depicted previously in Figure 3-4 may be subdivided based on hydrogeologic considerations to narrow the focus of the classification decision to the ground-water unit most relevant to the facility. For example, the hydrogeology may consist of two aquifers sep-

FIGURE 3-5
ILLUSTRATION OF A HYPOTHETICAL CLASSIFICATION REVIEW AREA

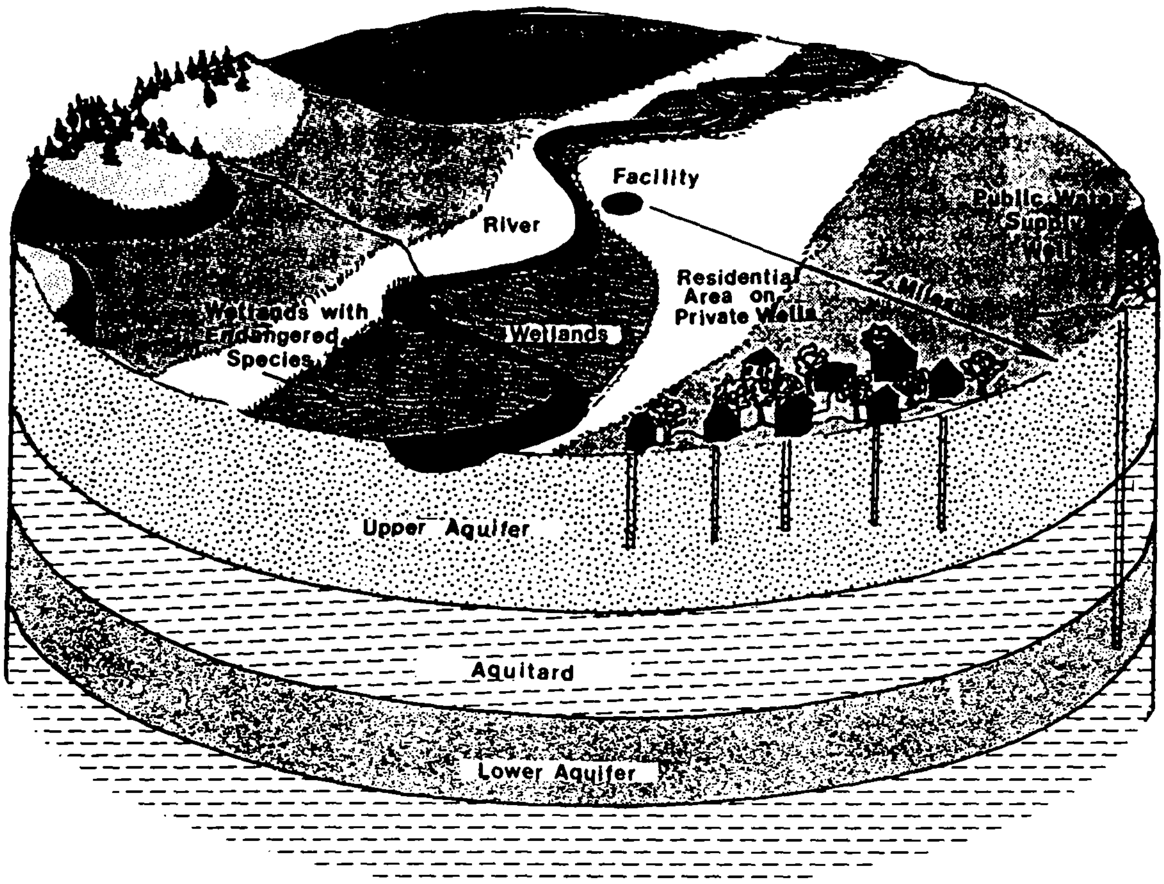
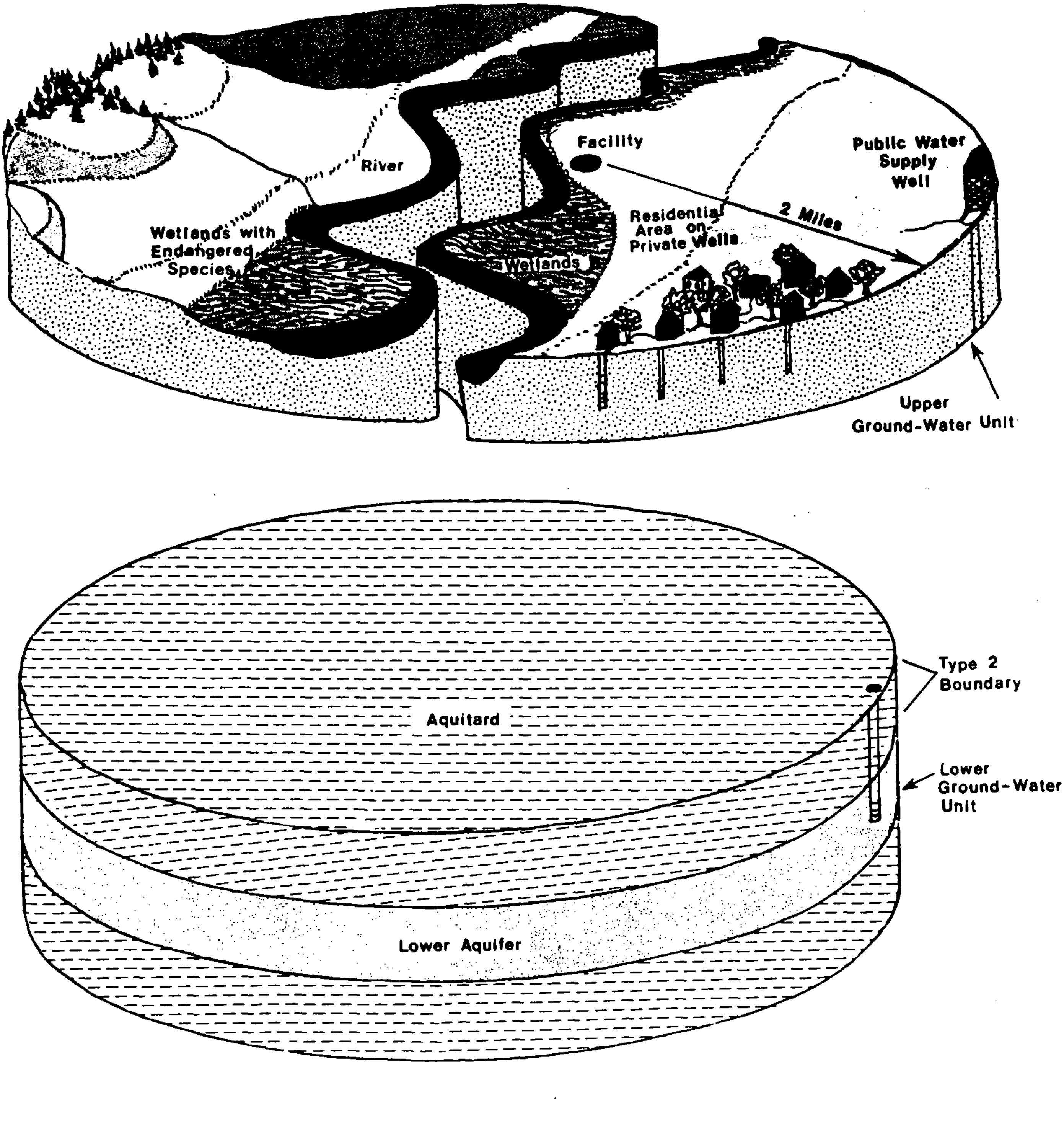


FIGURE 3-6
ILLUSTRATION OF A SUBDIVIDED CLASSIFICATION REVIEW AREA



arated by a thick, laterally extensive aquitard, as shown in the cross-section in Figure 3-5. If the aquitard is shown to satisfy all the criteria for a Type 2 boundary, then the Classification Review Area can be subdivided into two ground-water units as depicted in Figure 3-6. For an activity at the surface, the upper ground-water unit would be the most relevant to the classification decision. The lower ground-water unit would not be considered relevant and could be excluded from subsequent consideration in the classification process.

3.4 Key Terms and Concepts for Defining Class I

As mentioned previously, Class I encompasses those ground waters found to be highly vulnerable to contamination and defined as either an irreplaceable source of drinking water or as ecologically vital ground water. This section presents an expanded discussion for these, as well as supporting key terms and concepts.

3.4.1 Highly-Vulnerable Ground Water

Ground water which is highly vulnerable to contamination is characterized by a relatively high potential for contaminants to enter and/or to be transported within the flow system. This concept for classification purposes, focuses on the inherent hydrogeological characteristics of the Classification Review Area. Thus, vulnerability encompasses the leaching potential of the soil and/or vadose zone and the ability of the saturated flow system to move contaminants over a large geographic area (not just beneath any given site).

It should be noted that the Agency is providing two options for operationally defining vulnerability. Comments on these, as well as other approaches for assessing vulnerability, will be considered by the Agency in determining how best to incorporate this factor in classification decisions. Both approaches recognize that ground-water vulnerability occurs in a continuum from very low to very high vulnerability, just as soil leaching potential varies and saturated flow velocities vary from very low to very high. Advantages and disadvantages inherent in each option are provided.

Option A focuses on the use of the DRASTIC system (Aller et al, 1985), a numerical ranking system developed by the National Water Well Association, under contract to EPA. The DRASTIC method examines seven hydrogeologic characteristics of an area:

D - Depth to water table
R - net Recharge
A - Aquifer media
S - Soil media
T - Topography
I - Impact of the vadose zone
C - hydraulic Conductivity of the subject ground-water flow system

The DRASTIC method can be performed using readily available information on each of the above-listed characteristics. In most cases, for the purposes of classification, no new field work, drilling, or extensive mapping procedures should be required. The method yields a single numerical value, referred to as the DRASTIC index.

A two-tier DRASTIC criteria is proposed within Option A. The tiers are distinguished according to hydrologic regions. [redacted]is is done to incorporate some regional specificity based on this important parameter. [redacted] Procedures for using DRASTIC in the context of a classification exercise are provided in Part II Section 4.5.

The use of DRASTIC, furthermore, is commensurate with the idea that ground-water vulnerability (for classification purposes) should not vary according to the type of activity which is being evaluated. Vulnerability to contamination must, for the purposes of a universal classification, be independent of activity type. Otherwise, the class of ground waters may change with each activity; an approach which is inconsistent with state efforts, for example. Finally, the determination of vulnerability should not be inferred as a prediction of contaminant concentrations due to facility failure, or other contaminant release from the activity under consideration.

Among the various methods considered, DRASTIC has several advantages. It was prepared using a Delphi approach (a consensus building approach) on a panel of practicing, professional hydrogeologists familiar with the potential for ground-water contamination across the nation. It builds on earlier systems, such as those of the Le Grand System (LeGrand, 1980) and the Surface Impoundment Assessment System (Silka and Sweringer, 1978). It is applicable on a regional level (i.e., several square miles), on par with the size of the Classification Review Area. Furthermore, DRASTIC was designed to be used with readily available, regional hydrogeologic information. And it was also designed to overcome the problems of more simplistic methods (e.g., single-criterion or multiple-independent-criterion system) that may ignore relevant factors or the relative importance of a factor compared to other factors (see Appendix B for discussion of other approaches considered). Yet, it is relatively simple to use and includes the primary factors inherent to the area-wide vulnerability concept implied in classification decisions.

A distinct disadvantage of requiring the use of Option A is that it denies the user of the Guidelines the opportunity to consider other methods or to exercise full freedom of professional judgment where appropriate. In addition, some believe that the DRASTIC method may oversimplify the characterization of an area where the hydrogeology is very complex.

Under Option B, users of the Guidelines could, if they wish, consider the same parameters that are considered under the DRASTIC approach, but would not be compelled to use the DRASTIC system or the numerical cutoffs set forth in these Guidelines for determining what ground waters are "highly vulnerable." Rather, those classifying the ground water would take the various parameters into account in arriving at a professional judgment of whether the ground water is "highly vulnerable." The advantage of this approach is that it provides the person classifying the ground water with complete flexibility in considering the complexity of the particular site being evaluated. The disadvantage of this approach is that, since different though well-qualified professionals may reach different judgments under the same set of circumstances, some certainty, predictability, and reproducibility is sacrificed.

3.4.2 Irreplaceable Source of Drinking Water

A ground-water source may be classified as irreplaceable if it serves a substantial population, and, if reliable delivery of comparable quality and quantity of water from alternative sources in the region would be economically infeasible or precluded by institutional constraints. It is important to emphasize that the irreplaceability criterion is a relative test in that its goal is to identify those ground waters of relatively high value (compared to others). As a result, these may deserve to be treated as unique or "special." In order to consider a source of ground water to be irreplaceable, several factors must be addressed in more detail. "Substantial population" must be considered for all assessments. Where a substantial population is determined to be present, other factors must be assessed including:

- . uncommon pipeline distance
- . comparable quality
- . comparable quantity
- . institutional constraints,
- . economic infeasibility

In these draft Guidelines, the Agency is soliciting comment on approaches to judging the "replaceability" of current drinking water sources. Two options are presented to help frame the discussion. Option A would require, among other factors, a quantitative or semi-quantitative assessment of the population served by the source and the economic feasibility of replacing the source. Option B incorporates a qualitative assessment of the substantial population/economically irreplaceable factors. Under this approach, the size of the population served and the cost of using alternative sources would be evaluated, but not with the use of preferred methodologies accompanied by numerical cutoffs or other set criteria.

This section describes the factors that must be considered under either of the above alernatives and how they would be used in making a determination of "irreplaceability" under each alternative. Since Option A relies on specific techniques/cut-offs, it is discussed at greater length. Section 4.3 in Part II presents a more detailed description of methodologies, in particular for Option A, with additional background material being provided in the Appendices.

3.4.2.1 Substantial Population

Under Option A, the "substantial population" criterion can be met if at least 2500 people are served by:

- . well(s) on a public system (where the people live either inside or outside the Classification Review Area), and/or

- . private wells in a densely settled area (>1000 persons/sq mi).

Characteristics of U.S. public water-supply systems predominantly using ground water are described in the Federal Reporting Data System (FRDS). The system was developed by the U.S. EPA Office of Drinking Water to provide data on the size, characteristics, and compliance of public water systems. FRDS data shows that 10 percent of water-supply systems serve more than 2500 people. Thus, it generally defines areas of potentially high communal risk. That 10 percent, however, accounts for about 80 percent of the total U.S. population served by ground water. A more detailed discussion of the size of water-supply systems can be found in Appendix E.

Under Option B the relative size of the population served by the drinking water source would be one factor to consider in determining whether a source is "replaceable." The size of the population served, for example, will have to be taken into account in determining the economic feasibility of using alternative sources in the area. Thus, rather than using a formula and specific cutoff as would be required if the first approach were chosen, the user of the Guidelines would have the flexibility to balance various factors in determining whether a drinking water source is "irreplaceable."

3.4.2.2 Uncommon Pipeline Distance

Uncommon pipeline distance means a reasonable maximum distance over which water is piped in the region by populations of approximately the same size as the substantial population under consideration in the classification decision. The concept of uncommon pipeline distance was included in the irreplaceability criterion to make the classification process easier to implement. This criterion, although fairly general in nature, provides a means for estimating the limits of the area within which potential alternative water sources may be located. Without such a boundary, any water source in the country might be considered a replacement for any other water source, making the irreplaceability concept unworkable. This criterion is applicable under both Options A and B. A table presenting "uncommon pipeline distances" based on analyses of several water-supply systems is presented in Table 4-3. In all cases, this table merely provides general guidance and should be taken qualitatively.

3.4.2.3 Comparable Quality

The Agency has defined "comparable quality" in terms of the quality of raw sources of drinking water used in the area, considering, in a general way, both the types of contaminants that are present and their relative concentrations. The intent is to make rough order-of-magnitude comparisons to determine whether the potential alternative is of the same general quality as the source, and as other water used for drinking in the EPA Region, without conducting a specific, parameter-by-parameter comparison. This criterion is considered in the same manner in both Options A and B.

3.4.2.4 Comparable Quantity

The Agency intends "comparable quantity" to mean that the alternative source or sources, whether surface or ground water, is/are capable of reliably supplying water in quantities sufficient to meet the year-round needs of the population served by the ground water. This definition considers only the needs of the population at the time of the classification decision. In developing their own classification systems, states may choose, however, to consider modest population growth and increasing water needs over time. Again, this criterion would be considered in a similar manner under both Options A and B.

3.4.2.5 Institutional Constraints

For purposes of the classification system, the Agency defines institutional constraints as legal or administrative restrictions that preclude replacement water delivery and may not be alleviated through administrative procedures or market transactions. Institutional constraints can eliminate one or more possible alternative sources from consideration (and, likewise, indicate which alternate supplies are more viable than others) and, therefore, can necessitate a Class I irreplaceable designation. Such constraints limit access to alternative water sources and may involve legal, administrative, or other controls over water use.

EPA has placed potential institutional constraints into three categories:

(1) Probably Binding constraints -- which include treaties, agreements among states, and decisions by the U.S. Supreme Court that are not capable of being revised through market transactions or simple administrative processes

(2) Constraints which may possibly be binding -- such as, when market transactions, or simple administrative processes may not be able to provide an alternative source of water (e.g., limits on the source or amount of water that are created by state law)

(3) Constraints unlikely to be binding -- when market transactions, or simple administrative processes, usually can ensure an alternative source of water.

These factors would be evaluated in a similar way in both Options A and B.

3.4.2.6 Economic Infeasibility

To frame the Agency's consideration of "replaceability" for classification purposes, two options are specifically presented for public comment. In Option A, an alternative source of replacement water is economically infeasible if the annual cost to a typical user would exceed 0.7 to 1.0 percent of the mean household income in the area. EPA is proposing a threshold in this range and is seeking comment on the applicability of this economic test and/or other thresholds. Appendix G provides a detailed discussion of these tests.

Although the economic infeasibility criterion suggests an "ability to pay" measure, this does not mean that users of the water would be expected to pay for a replacement source in the highly unlikely event of contamination. Rather, this approach is intended solely as a relative test to identify those waters deserving of special protection.

This criterion does not require a rigorous analysis, but rather a general understanding of the alternative source(s) and rough estimates of replacement costs. To perform this analysis, data in the following areas are needed:

- Physical characteristics of the alternative water sources

- Estimates of capital and operating costs for using the alternative source

- Household incomes of the ground-water users.

In most instances, generally available data will be sufficient to apply this test. Simple, inexpensive estimation techniques will be adequate.

In Option B, the cost of replacing a drinking water source would be one factor in judging its "replaceability." This cost could be taken into account along with the community's ability and/or willingness to pay for alternative water sources in judging whether it is truly economically infeasible to replace the water. Recommended methods, approaches, or criteria would not be incorporated by guidance. Best professional judgement in specific situations would be the basis for decisions. To cite one example, water suppliers in some cases may be "financially constrained" in their ability to provide alternative water. These limitations could be addressed in a qualitative manner.

3.4.3 Ecologically Vital Ground Water

As a result of the guidelines development process, ecologically vital ground water (Figure 3-7) is defined as supplying a sensitive ecological system supporting a unique habitat.

Underlined in the above statement are the two terms which require further definition. A sensitive ecological system is interpreted in these guidelines as an aquatic or terrestrial ecosystem located in a ground-water discharge area. A unique habitat is primarily defined as a habitat for a listed or proposed endangered or threatened species, as designated pursuant to the Endangered Species Act (as amended in 1982). In some cases, certain Federal land management areas, congressionally designated and managed for the purpose of ecological protection, may also be considered unique habitats for ground-water protection, regardless of the presence of endangered or threatened species per se. Among those most likely to be included are:

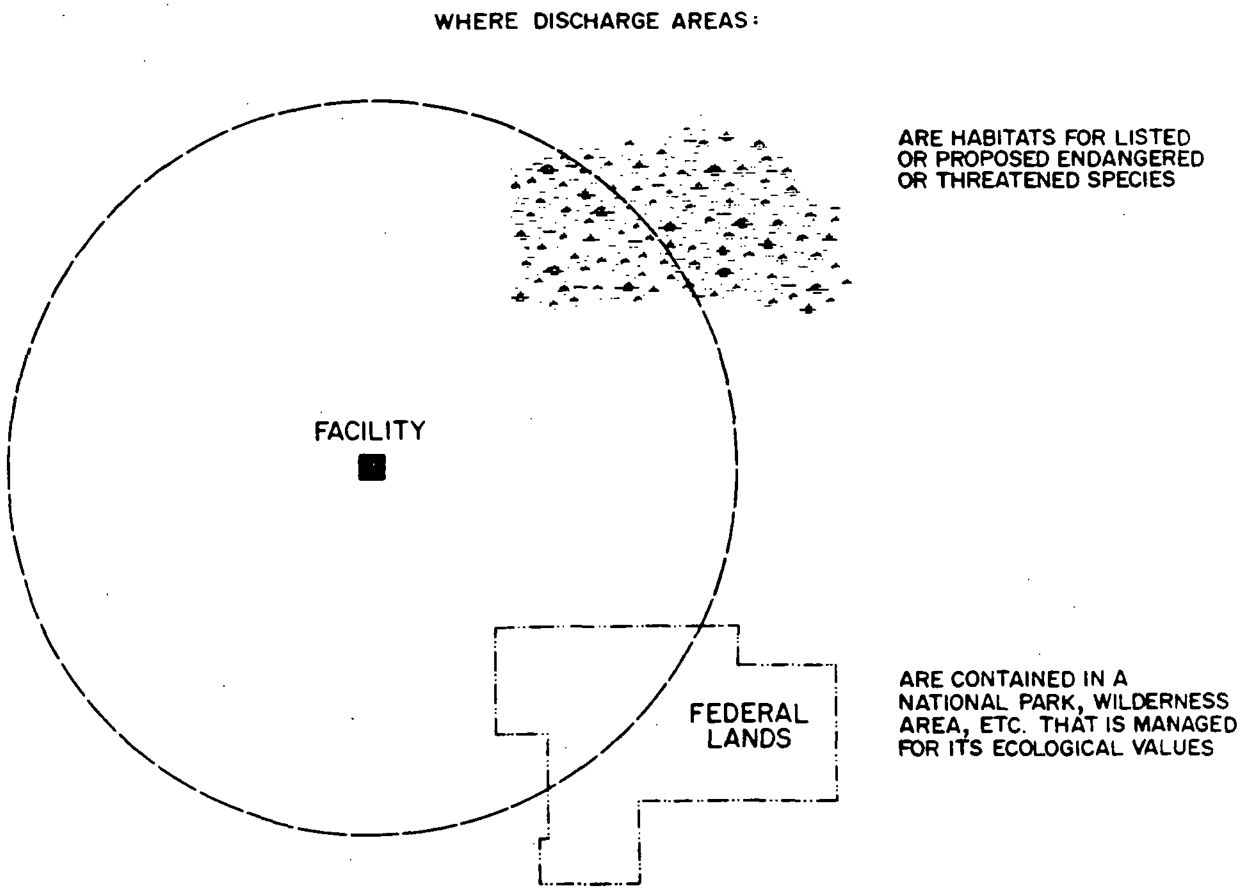
- Portions of National Parks
- National Wilderness Areas
- National Wildlife Refuges
- National Research Natural Areas.

A discharge area is an area of land beneath which there is a net annual transfer of water from the saturated zone to a surface water body, the land surface, or the root zone. The net discharge is physically manifested by an increase of hydraulic heads with depth (i.e., upward ground-water flow). These zones may be associated with natural areas of discharge, such as seeps, springs, caves, wetlands, streams, bays, or playas.

3.5 Key Terms and Concepts for Defining Class II

Class II encompasses all non-Class I ground water currently used, or potentially available, for drinking and other beneficial uses, whether or not it is particularly vulnerable to contamination. Class II has been subdivided into two subclasses which comprise the major key terms: current source of drinking water and potential source of drinking water.

FIGURE 3-7
EXAMPLE CLASS I - ECOLOGICALLY VITAL GROUND WATER



3.5.1 Current Source of Drinking Water

Ground water is considered a current source of drinking water under two conditions (Figure 3-8). The first and most common condition is the presence of one or more operating drinking-water wells (or springs) within the Classification Review Area. The second condition occurs in the absence of wells or springs, and includes ground-water discharge to a surface water reservoir used as a drinking-water supply. It requires the presence within the Classification Review Area of a water-supply watershed reservoir (or portion of a water-supply reservoir watershed) designated for water- quality protection, by either State or local government.

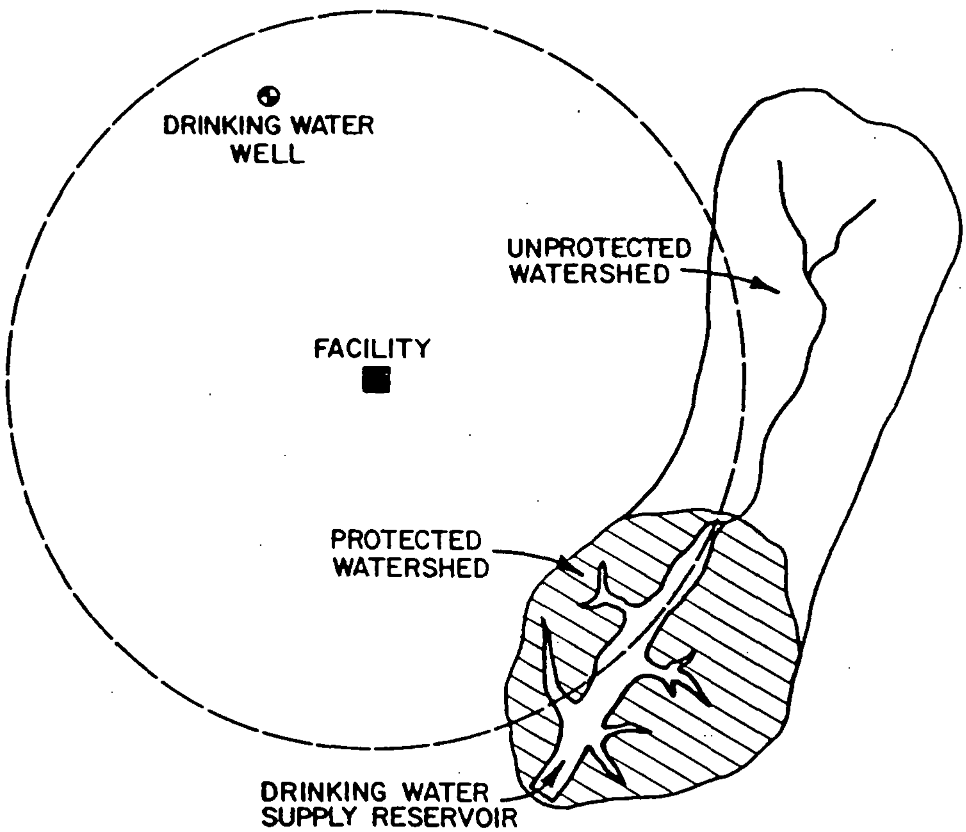
The concept of a current source of drinking water is rather broad by intent. Only a portion of the ground water in the Classification Review Area needs to be supplying water to drinking-water wells. It should also be noted that a current source of drinking water, which meets the irreplaceable/ highly vulnerable criteria, is Class I.

3.5.2 Potential Source of Drinking Water

A potential source of drinking water in the Classification Review Area is one which is capable of yielding a quantity of drinking water to a well or spring sufficient for the needs of an average family. Drinking water is taken specifically as water with a total-dissolved-solids (TDS) concentration of less than 10,000 mg/l, which can be used without treatment, or which can be treated using methods reasonably employed in a public water-supply system. The sufficient yield criterion has been established at 150 gallons/day (see Section 3.6.2 for the rationale). Ground water not currently used for a source of drinking water will be classified as a potential source of drinking water, unless demonstrated otherwise.

An uppermost limit of 10,000 mg/l TDS was chosen for several reasons. Many State and Federal programs currently use 10,000 mg/l TDS to distinguish potable from non-potable water. Some states set lower limits because the TDS of drinking water is usually well below 10,000 mg/l. A survey of rural water supplies (EPA, 1984), for which ground water was the principal source, found a maximum TDS level of 5949 mg/l. Eighty-five percent of rural water-supply systems were less than 500 mg/l TDS. Given the range of TDS values, 10,000 mg/l provides the flexibility needed in a nationwide program. It also ensures that other beneficial uses of ground water will receive substantial protection.

FIGURE 3-8
EXAMPLE CLASS II - CURRENT SOURCE OF DRINKING WATER



Establishing a minimal yield (i.e., to wells and springs) in the definition of potential source is consistent with the hierarchy of resource values reflected in the classification scheme. Areas where all water-bearing materials fail the "sufficient-yield" criterion will have little, if any, resource value for drinking water and, therefore, fall into Subclass IIIA.

By a de facto assumption, any ground water not a current source of drinking water will be classified as a potential source of drinking water, unless a lower resource value is demonstrated. This approach was chosen because it enables EPA to set a minimum Federal "floor" which provides broad protection while placing the burden of proof on the person(s) interested in demonstrating that the subject ground water meets the criteria for a lower class of ground water. Figure 3-9 indicates the concept of a potential source of drinking water.

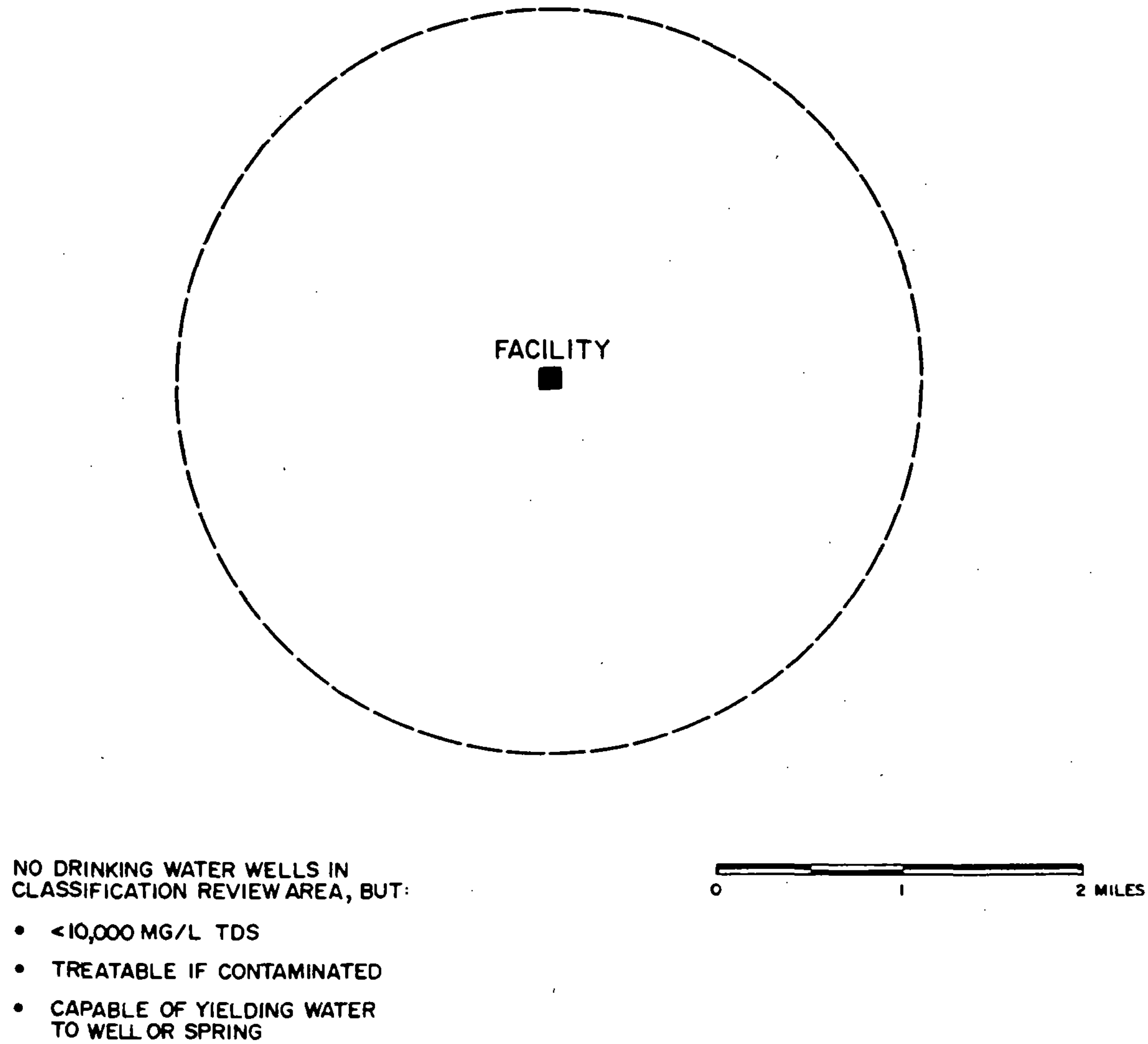
3.5.2.1 Water Quality/Yield Data Needs

Specific data needs for water-quality testing and water-yield testing were not established as part of the Class II criteria. The general rule is to presume, in the absence of data, that the quality and yield of a ground-water resource is sufficient to meet the criteria for a potential source of drinking water. Where the ground water can be demonstrated to fail the quality or yield criteria, the result could be a Class III designation.

3.5.3 Sufficient Yield

The definition of a potential source of drinking water implies a yield sufficient to meet the long-term basic needs of an average family by a well or spring. The sufficient yield criterion was established at 150 gallons-per-day (see Section 3.6.2 for rationale). In cases where the Classification Review Area or the appropriate subdivision of the Classification Review Area does not contain a well or spring routinely used for drinking water, and can be shown to have insufficient yield, then a designation of Subclass IIIA, for the ground waters in the Classification Review Area or its subdivisions (as described in Section 3.6.2), is possible. As mentioned previously, unless it is demonstrated otherwise, the Classification Review Area is presumed to meet the sufficient yield criterion.

FIGURE 3-9
EXAMPLE CLASS II - POTENTIAL SOURCE OF DRINKING WATER



3.6 Key Terms and Concepts for Defining Class III

The third class of ground water encompasses those waters which are not potential sources of drinking water due to:

1) salinity (i.e., greater than 10,000 mg/l total dissolved solids),

2) contamination, either by natural processes or by human activity (unrelated to a specific polution incident), that cannot be cleaned up using treatment methods reasonably employed in public water-supply systems (or economically treated), or

3) insufficient yield at any depth to provide for the needs of any average-size household.

Subclasses are differentiated based primarily on the degree of interconnection to adjacent waters (i.e., surface waters and/or ground water of a higher class).

The key terms and concepts underlined above are defined in this section.

3.6.1 Methods Reasonably Employed in Public Water Treatment Systems

Ground water may be considered "untreatable" if, in order to meet primary drinking water standards and other relevant Federal criteria or guidelines, treatment techniques not included on a reference list of commonly applied technologies must be used. The focus on public-water system techniques (rather than all technologies) was established in the Ground Water Protection Strategy. The reference list has been designed to account for variations in the use, availability, and applicability of treatment technologies in an EPA Region. This approach is a relatively simple decision framework that does not involve detailed engineering or cost analyses. An optional approach which focuses on treatment costs compared with total system costs is presented for review and comment in Appendix G.

For application to the classification system, EPA has made an inventory of all known or potential water- treatment technologies and classified each as belonging to one of three categories:

- Methods in common use that should be considered treatment methods reasonably employed in public water-treatment systems,

- Methods known to be in use in a limited number of cases that may, in some regions because of special circumstances, be considered reasonably employed in public water-treatment systems, and

- Methods not in use by public water-treatment systems.

Methods in common use include aeration, air stripping, carbon adsorption, chemical precipitation, chlorination, flotation, fluoridation, and granular media filtration.

Methods known to be used under special circumstances include: desalination (e.g., reverse osmosis, ultrafiltration, and electrodialysis), ion exchange, and ozonation. In most EPA Regions, these treatment methods should not be considered methods reasonably employed by public water systems. In certain EPA Regions, because of special ground-water quality or water scarcity circumstances, they may be considered reasonably employed.

Treatment methods not in use by public water treatment systems include: distillation and wet air oxidation. These methods are considered new to water treatment although they have been applied for industrial purposes in the past. Since their application to water treatment is experimental at this time, they should not be considered treatment methods reasonably employed in public water systems.

It should be stressed that some techniques such as granular media filtration are used by public water- treatment plants for polishing (e.g., final treatment). These techniques may be insufficient to adequately treat for heavily contaminated ground water. In such cases, where unrelated to a given source of pollution, a Class III designation is likely. In other cases where the listed treatment techniques are in use and would be equally effective and insignificantly more costly to apply to the contaminant under consideration, the water would be considered "reasonably treatable" and not Class III.

Treatment capacity to handle certain concentrations or combinations of contaminants may not be employed in a region, although the basic technologies are available. In these cases, the optional economics-based tests may be preferential to the reference technology approach.

3.6.2 Insufficient Yield at Any Depth

In order to establish Subclass IIIA on the basis of insufficient yield, two conditions must be met within the

Classification Review Area or appropriate subdivision of the Classification Review Area. These conditions are:

(1) There are no wells or springs used as a source of drinking water regardless of well yield.

(2) All water-bearing units meet the insufficient yield criterion.

Given variability in regional aquifer characteristics and climate, a value of 150 gallons-per-day was selected as the cutoff for sufficiency. This level of production should be possible throughout the year, in order to qualify as a potential source of drinking water. The yield can be obtainable from drilled wells, dug wells, or any other method. Agricultural, industrial, or municipal uses of these marginal water-bearing areas would require significantly higher yields than a domestic well and would, therefore, be unable to use this low-yield ground water as a water source. The figure is based on a conservatively low yield below which it is considered unlikely or impractical to support basic household needs.

In setting the sufficient yield criterion, EPA consulted its own guidelines concerning water needs and related waste flows for single family dwellings. EPA's water-supply guidelines indicate that per capita residential water needs range from 50 to 75 gallons-per-day (EPA, 1975) for a single family residence. Waste flows from single family dwellings using septic systems average 45 gallons-per-day per capita (EPA, 1980, page 51). Using an average family size and a per capita water need of approximately 50 gallons-per-day, the well-supply criterion was established at approximately 150 gallons-per-day. (Note that, to be on the conservative side, this assumption of household usage is the lowest figure used in these guidelines.)

3.6.3 Interconnection as a Class III Criterion

The subclasses of Class III ground water are differentiated in part by the relative degree of interconnection between these waters and those in adjacent ground-water units and/or surface waters. A discussion of ground-water units and the concept of degrees of interconnection is provided in Section 3.3. Subclass IIIA ground-water units are defined to have a high-to- intermediate degree of interconnection to adjacent ground-water units or surface waters. Subclass IIIB ground-water units are defined to have a low degree of interconnection to ground-water units of a higher class or surface waters within the Classification Review Area.

PART II

DETAILED CLASSIFICATION PROCEDURES

PART II

4.0 CLASSIFICATION PROCEDURES

The previous sections provide both background and overview of the EPA ground-water classification system. The system is based on an analysis of data which is generally available from published sources, telephone or in-person contacts, or other program-related sources, such as permit packages and environmental impact statements. The need for detailed information on the hydrogeologic or socioeconomic properties of an area will increase, for example, where a Class I or Class III designation is possible, or a sub-division of ground waters in the Classification Review Area is being considered. In the majority of decisions, data gathering and interpretation will be simple and inexpensive.

This chapter provides a more in-depth discussion of the actual process of site-by-site classification. The process is facilitated through a classification procedural chart shown in Figure 4-1. A corresponding classification "work-sheet" (Table 4-1) follows the sequence of procedural chart steps. Classification will typically begin with step one and continue until a final class determination is made. Both the procedural chart and worksheet were developed to provide a systematic approach to classifying ground water based on certain criteria, e.g., presence of wells, ecologically vital areas, water quality, irreplaceability, etc. They are provided as suggested approaches only, since a given setting may be more effectively handled through another sequence of steps.

It is important to realize that, as a result of the classification procedure, the Agency is not classifying a specific ground-water region, per se. The classification process will assist the EPA programs in such activities as permitting and corrective-action assessments. No mapped unit will be generated, although a Classification Review Area will be employed as an aid in the decision process.

Lastly, the system assumes a broad definition for current use as a source of drinking water (IIA). In the absence of current use, the system will lead to a determination of potential source of drinking water (IIB), unless a lower resource value is demonstrated. Other beneficial uses of ground water will be considered in making Class II determinations.

FIGURE 4-1
PROCEDURAL CLASSIFICATION CHART

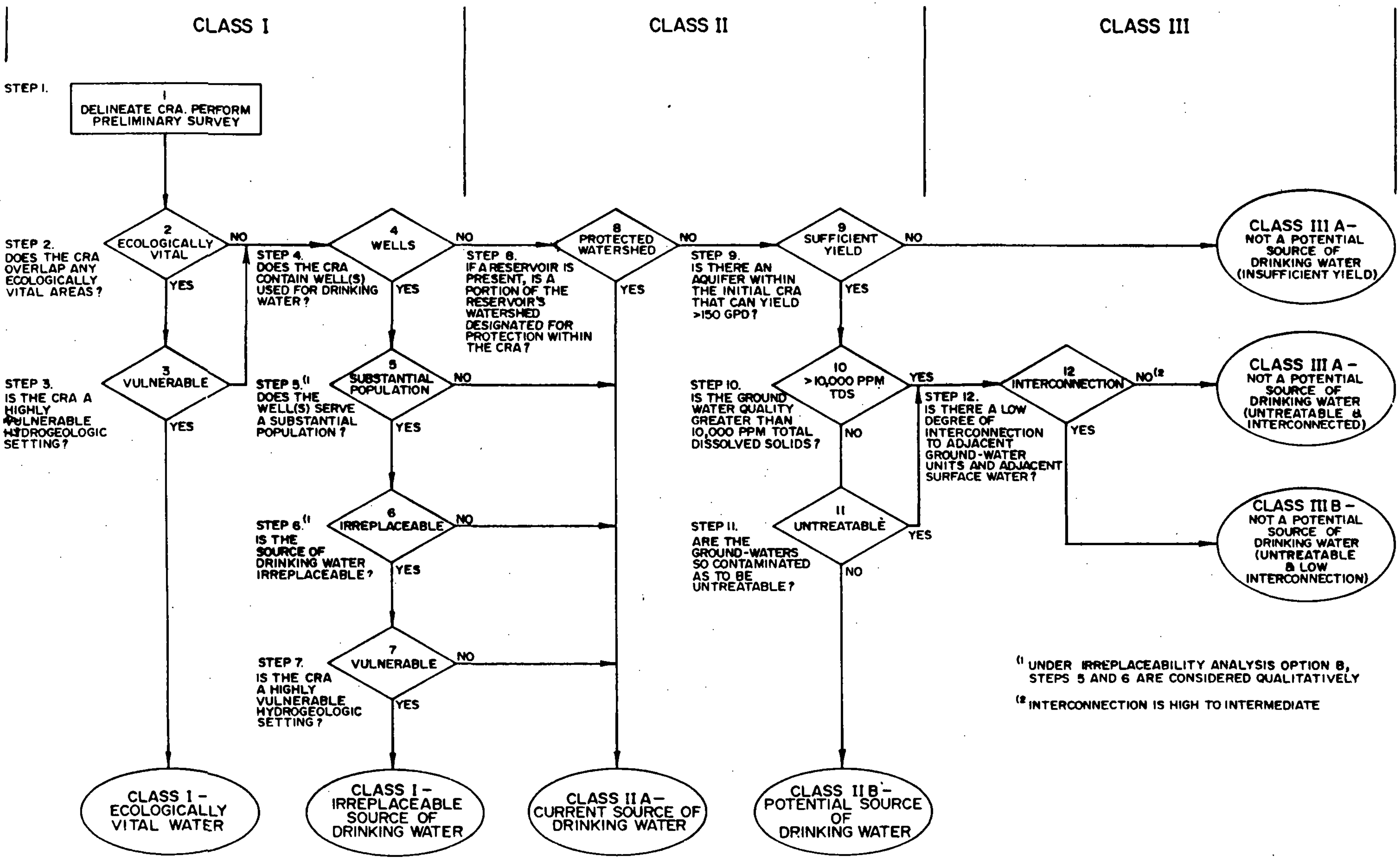


TABLE 4-1
CLASSIFICATION WORKSHEET

Step	Question/Direction	Response/Comment*
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional- Demonstrate subdivision(s) of the CRA	
2	Locate any ecologically vital areas in the CRA.** Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	
3	Perform vulnerability analysis. Is the CRA or appropriate subdivision a highly vulnerable hydrogeologic setting? . Yes, then the ground water is CLASS I-ECOLOGICALLY VITAL . No. go to next step	
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, to to next Step . No, go to Step 8	

*To be completed when performing classification.
**Steps 2 and 3 may be performed in reverse order.

Step	Question/Direction	Response/Comment*
5*	Inventory population served by well(s). Does the well(s) serve a substantial population? . Yes, go to next step . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	
6*	Unless proven otherwise, the drinking water source is assumed to be irreplaceable. Optional-perform irreplaceability analysis. Is the source of drinking water irreplaceable? . Yes, go to next step . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	
7	Perform vulnerability analysis. Is the CRA or appropriate subdivision a highly vulnerable hydrogeologic setting? . Yes, then the ground water is CLASS I-IRREPLACEABLE SOURCE OF DRINKING WATER . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	

*Under irreplaceability analysis Option B, Steps 5 and 6 are considered qualitatively.

Step	Question/Direction	Response/Comment*
8A	Determine location of reservoirs within the CRA or appropriate sub-division. Does the CRA or appropriate subdivision contain reservoirs used for drinking water? . Yes, go to next step . No, go to Step 9	
8B	Determine status of watershed(s) containing reservoir(s) present in the CRA or appropriate subdivision. Does that portion of the water-shed designated for water-quality protection overlap the CRA or appropriate subdivision. . Yes, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER . No, go to next step	
9	Determine yield from ground-water medium (total depth across CRA or appropriate subdivision). Can it yield 150 gallons-per-day to a well? . Yes, go to next step . No, then the ground water is CLASS IIIA-NOT A SOURCE OF DRINKING WATER (INSUF-FICIENT YIELD)	

Step	Question/Direction	Response/Comment*
10	Determine water-quality characteristics within the CRA or appropriate subdivision. Is the water quality greater than 10,000 mg/l total dissolved solids (TDS)? (Note: If water quality is unknown, then this question must be answered no.) . Yes, go to Step 12 . No, go to next step	
11	Are the ground waters so contaminated as to be untreatable? (Note: If water quality is unknown, then this question must be answered no.) . Yes, go to next step . No, then the ground water is CLASS IIB-POTENTIAL SOURCE OF DRINKING WATER	
12	Perform interconnectedness analysis. Is there a low degree of interconnection between the ground water being classified and adjacent ground units or surface waters within the initial CRA? . Yes, then the ground water is CLASS IIIB-NOT A SOURCE OF DRINKING WATER (LOW INTERCONNECTION) . No, then the ground water is CLASS IIIA-NOT A SOURCE OF DRINKING WATER (INTERMEDIATE-TO-HIGH INTERCONNECTION)	

4.1 Preliminary Information

An overview of basic information needs for classification is presented in this section. More detailed discussions are provided in the balance of this chapter as well as in the Appendices. The collection of preliminary information is meant to reflect an approach to classification which begins simply and directly. The data should be collected from the most current and best available sources. It should include a well/reservoir survey, demographic information, and identification of ecologically vital areas. Regional hydrogeologic data will be required if an interconnection analysis needs to be made. Otherwise, a general description of the regional geology, geomorphology, and hydrogeology would be useful. Again, the emphasis is on available information rather than on detailed in-field analyses.

4.1.1 Base Map of Classification Review Area

The Classification Review Area is defined by drawing a two-mile radius from the boundaries of the facility or activity area. An expanded review area is allowed under certain hydrogeologic conditions of intermediate-to-high ground-water velocities. These conditions and the procedures to expand the Classification Review Area are presented in Section 4.2. This Classification Review Area may be subdivided based on a hydrogeological analysis of interconnection between adjacent surface waters and ground-water units as described in Section 4.3. A base map illustrating the facility location, and the Classification Review Area boundary is, of course, a vital piece of basic data.

4.1.2 Well Survey

A well survey should include the location, use, and pumpage capacity of existing public water-supply wells or well fields within the Classification Review Area. Public water-supply systems are defined under the Safe Drinking Water Act as those serving more than 25 persons or with more than 15 service connections. Information on the well depth and screened interval depth may be needed if a subdivision of the Classification Review Area is to be made.

A detailed inventory of private residential wells is not necessary. As pointed out in Section 4.4, census data (e.g., densly settled areas) can be a good estimation approach. As a preliminary step, the delineation of areas not served by public water supplies, and the approximate number or density of homes in the area should be obtained. The simplest well data to be included are the estimated number of wells present, and other general characteristics of private wells in the Classification Review Area.

Well information may be obtained from water authorities, public health agencies, regulatory agencies permitting well drilling, well drillers, or other state or local entities. Sources of the data should be documented and, where the information is not available, it should be so stated.

Water-supply reservoirs designated for water-quality protection in the Classification Review Area need to be identified and described. Again, state and local agencies may be utilized in this capacity. Water-supply reservoir watersheds designated for water-quality protection are specifically recognized in the ground-water classification system.

4.1.3 Demography

Information on populations served by public and private wells will be needed if it is apparent that substantial populations may be involved, which could lead to a Class I decision. A first-cut approximation for public supply wells in the area can be made by dividing the total pumpage capacity by the typical per capita consumption rates for the region. Estimates of the number of private wells in densely settled areas within the Classification Review Area will also be necessary. Densely settled areas can be located on U.S. Census Bureau maps. Procedures for determination of substantial population are provided in Section 4.4.

4.1.4 Ecologically Vital Areas

Identification of areas which may be candidate discharge points for ground water is a first step in locating ecologically vital areas. Such areas may include springs, streams, caves, lakes, wetlands, estuaries, coastlines, embayments, and playas. Once these candidate discharge areas have been identified (since proving discharge may require field studies), the presence of a habitat for a listed or proposed endangered or threatened species (pursuant to the Endangered Species Act as amended in 1982) needs to be examined. The location of any such areas, or any Federal lands managed for ecological values within the Classification Review Area must be identified. The Regional Office of the U.S. Fish and Wildlife Service and the State Endangered Species coordinator or Heritage Program administrator are two sources for information regarding unique habitats and/or endangered or threatened species. Information about Federal lands may also be obtained from Federal land management agencies such as the National Park Service, U.S. Forest Service, and Bureau of Land Management. The presence of Federal lands is indicated on most state and county road maps and U.S. Geological Survey quadrangle sheets.

4.1.5 Hydrogeologic Data

Regional hydrogeologic information will be needed, to some extent, in order to perform a DRASTIC analysis for the vulnerability criterion; estimates are needed on:

- depth to water
- net recharge
- uppermost aquifer media
- soil media
- topography (slope)
- vadose zone media
- hydraulic conductivity of the uppermost aquifer.

This information is typically reconnaissance in nature and may likely be obtained from county/regional reports and also State geologic surveys. Pertinent information will be obtained from U.S. Geologic Survey cross-sections, topographic maps, stratigraphic sections, county geologic maps, and U.S. Department of Agriculture soil maps.

If interconnectedness of ground water with adjacent ground units and surface waters is to be analyzed, additional detailed hydrogeologic information is necessary. This might include descriptive hydrogeologic data, aquifer test data from previous studies, semi-quantitative flow nets, computer simulations, or other relevant information. This information is critical for all Class III demonstrations. Specific considerations for interconnection to adjacent water is described in Section 4.3.

The best available sources of published hydrologic/-geologic information are the U.S. Geological Survey publications, State geological surveys, scientific books and journals, and U.S. Department of Agriculture county soil surveys. Data supporting facility permit applications, Clear Water Act Section 208 studies, as well as Environmental Impact Statements, may also be useful.

4.2 Conditions and Procedures for Expanding the Classification Review Area

Expansion of the Classification Review Area is allowed under certain hydrogeologic conditions. The two-mile radius may be insufficient for determining the use and value of ground water and identifying potentially affected users in hydrogeologic conditions of intermediate to very high ground-water flow velocities where these velocities occur over distances much greater than two miles. In such settings, there is a potential for activity-related contaminants to move beyond a two-mile radius in a relatively short time frame, especially under the influence of large-scale ground-water withdrawals. This section represents qualitative descriptions of those hydrogeologic settings where an expanded review area is appropriate, and the procedures to quantitatively establish the dimensions of the expanded review area based on hydrogeologic characteristics.

An expansion of the Classification Review Area will be triggered upon the determination that the activity under review occurs within two hydrogeologic settings. Because these settings are described qualitatively, some level of hydrogeologic information will be needed to match the real settings to qualitative description.

4.2.1 Hydrogeologic Settings

Two hydrogeologic settings have been identified where expansion of the Classification Review Area is appropriate. They are:

A. Settings (referred to as Karst settings) where the principle aquifer is relatively shallow (<100m) and composed of carbonate rocks, with a well developed system of solution-enlarged openings (secondary porosity). The solution-enlarged openings serve as the main conduits for ground-water flow and are interconnected into distinct but dynamic ground-water basins feeding a complex of cave streams. These settings are often referred to as karst areas or karst aquifers. Flow through the conduit system is extremely rapid, as much as 1800 ft-per-hour (Quilan and Ewers, 1985) over long distances, in some cases up to 15 miles. Settings may be found in the following ground-water regions (after Heath, 1984):

6. Non-Glaciated Central Region
7. Glaciated Central Region
10. Atlantic and Gulf Coastal Plain Region
11. Southeast Coastal Plain Region, and
15. Puerto Rico and the Virgin Islands.

B. Certain settings (referred to as alluvial basin settings) where the general length of ground-water flow paths are significantly greater than the two-mile Classification Review Area radius (i.e., where the distance between perennial streams is greater than four miles). These settings are predominantly alluvial basins and other basins filled with unconsolidated to semi-consolidated materials and are, in addition, characterized by:

- An unconfined aquifer as the dominant aquifer
- Losing streams as the predominant source of recharge
- Transmissivities and flow velocities that are moderate to high (>250 m^2/d and >60 m/yr, respectively)
- Relatively low annual rain fall (less than 20 inches)

The ground-water regions (after Heath, 1984) where these settings can be found include:

2. Alluvial Basin Region
3. Columbia Lava Plateau Region
4. Colorado Plateau and Wyoming Basin Region
5. High Plains Regions, and
6. Non-Glaciated Central Region.

4.2.2 Expanded Classification Review Area Dimensions

The dimensions of the expanded review area are governed by the hydrogeologic characteristics of the region. Flow-system boundaries, flow direction, and flow velocities are the key characteristics.

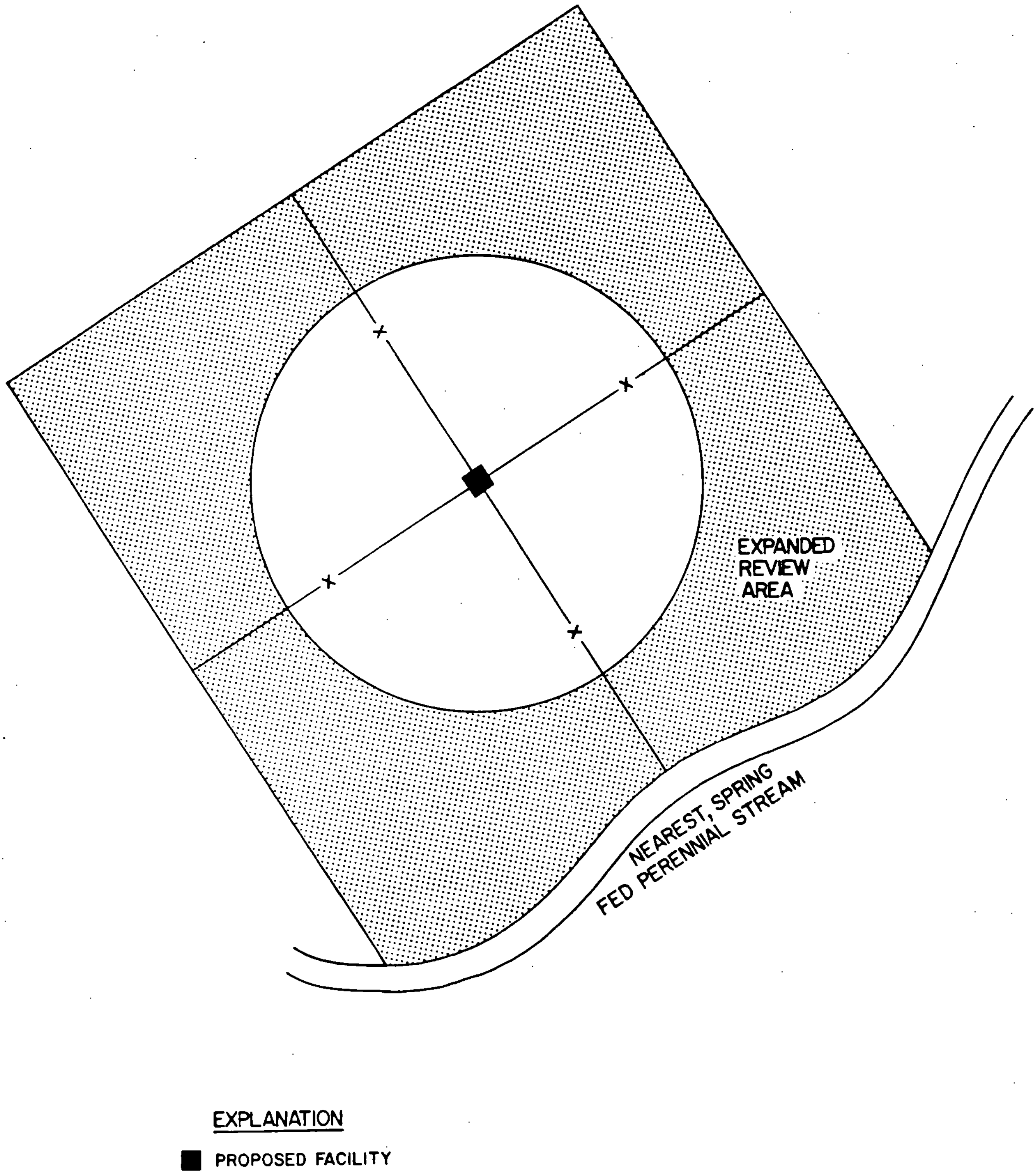
For Setting A, karst areas, the expansion area dimensions will be based on boundaries of the ground-water basin(s) encompassing the activity. A basin includes all recharge areas supplying the cave stream extending to the perennial stream where the cave-stream discharges. These basins can be mapped using dye-tracing studies and a water-level map. However, due to the expense of such studies, few basins have been mapped. As a surrogate, it is recommended that the distance to the nearest spring-fed, perennial stream be employed to establish the expanded review-area dimensions as shown in Figure 4-2. The reviewer is cautioned that, in some cases, the nearest perennial stream may not be the discharge for the subject ground-water basin. Such an error can be minimized by locating the topographic high (the water-shed divide) between the nearest perennial stream and adjacent streams. If the activity is on the same side of the topographic high as the nearest perennial stream, then it is reasonable to assume that the nearest perennial stream is the discharge. If not, then the discharge is likely to be the perennial steam on the same side of the topographic high as the activity/facility. In rare cases, the activity or facility is located on the topographic high. In such a case, the expanded review area should extend to the nearest perennial stream on all sides of the topographic high.

For Setting B, alluvial basins, the dimensions of the expanded review area are based on the average ground-water flow velocity within the basin. The radius is to be extended to a distance that ground water will flow in a period of 50 years. For example, if flow velocities averaged 400 feet-per-year, then the expanded radius would be 20,000 feet, approximately four miles. In the event that ground-water flow velocities are unknown, an expanded radius of five miles is recommended.

Ground-water flow velocities range over several orders-of-magnitude. The highest velocities are those of the karst cave streams. In alluvial basins, it will be unlikely that flow velocities as high as one mile a year will occur except over very short distances not representative of flow throughout the basin.

The dimensions of the expanded review area can be modified to account for the direction of flow. Where flow direction can be reliably determined, only the downgradient portion of the expanded review area need be examined. The expanded review area can also be subdivided according to rules outlined in Section 4.3. Examples of expanded Classification Review Area for both a Karst setting and an alluvial basin setting are provided in Appendix C case studies 10 and 11, respectively.

FIGURE 4-2
EXAMPLE OF GEOMETRY AND DIMENSIONS OF THE PROPOSED
EXPANDED REVIEW AREA FOR KARST SETTINGS



4.3 Subdivision of the Classification Review Area: Identification of Ground-Water Units and Analysis of Interconnection Between Ground-Water Units

The ground-water regime defined in Chapter 3.0 can be subdivided into three-dimensional, mappable ground-water units. The Classification Review Area, regardless of size, may be subdivided to allow more precise definition of the specific ground-water units where classification should be focused. This chapter presents the methods and examples by which subdivisions are identified and how the degree of interconnection between the subdivisions is analyzed.

Subdivision of a Classification Review Area may be carried out to separate ground-water units having different use and value and, therefore, are subject to different degrees of protection. For example, the subdivision of the Classification Review Area will be necessary to justify the following types of conclusions:

- Deep ground-water units with Class IIIB water are overlain at shallow depth by ground-water units with Class I or II water,

- The ground-water unit associated with an activity does not discharge to an ecologically vital area present in the Classification Review Area,

- A shallow, ground-water unit that is a potential source of drinking water (Class IIB) is underlain by a deeper ground-water unit that is currently used as a source of drinking water (Class IIA)

Having identified the ground-water units within the Classification Review Area, the user of this document is ready to classify the waters within the units in accordance with the methods set forth in other sections and schematically summarized in Figure 4-1. The interrelationship between ground-water unit subdivisions and the classification of ground water are as follows:

- All ground water within a ground-water unit has a single class designation.

- Boundaries separating waters of different classes must coincide with boundaries of ground-water units,

- One or more adjacent ground-water units may have the same class designation.

Ground-water units are delineated on the basis of three types of boundaries described below:

Type 1: Permanent ground-water flow divides. These flow divides should be stable under all reasonably foreseeable conditions, including planned manipulation of the ground-water regime.

Type 2: Extensive, low-permeability (non-aquifer) geologic units (e.g., thick, laterally extensive confining beds), especially where characterized by favorable hydraulic head relationships across them (i.e., direction and magnitude of flow across the low-permeability geologic unit). The most favorable hydraulic head relationship is where flow is toward the ground-water unit being classified and the magnitude of the head difference (hydraulic gradient) is sufficient to maintain this direction of flow under all foreseeable conditions. The integrity of the low permeability unit should not be interrupted by improperly constructed or abandoned wells, extensive, interconnected fractures, mine tunnels or other apertures.

Type 3: Permanent fresh water-saline water contacts (saline water defined as those waters with greater than 10,000 mg/l of Total Dissolved Solids). These contacts should be stable under all reasonably foreseeable conditions, including planned manipulation of the ground-water regime.

The degree of interconnection between ground-water units is related to the type of boundary. A high degree of interconnection is assumed for all waters within a single ground-water unit. Adjacent units that are separated by a Type 1 (ground-water flow divide) or Type 3 (fresh water-saline water contact) boundary have an intermediate degree of interconnection. Adjacent units separated by a Type 2 (low-permeability geologic unit) boundary have a low degree of interconnection.

The degree of interconnection across the three boundary types defined here depends on selected key physical and chemical processes governing movement of water and dissolved solute in the subsurface. Under steady/state ground-water flow conditions the principal mechanisms effecting potential contaminant movement across Type 1 (ground-water flow divide) or Type 3 (salinity difference) boundaries would be mechanical dispersion and chemical diffusion. These conditions are considered by EPA to represent an intermediate degree of interconnection. Under transient flow conditions caused by pumpage or accelerated recharge of fluids within the Classification Review Area, there exists the potential to spatially displace a ground-water flow divide or saline/fresh water interface boundary. For this reason EPA believes that foreseeable changes in aquifer stresses and increased ground-water use in the Classification Review Area should be considered in determining the permanence (i.e., location over time) of such boundaries.

The primary mechanism for contaminant transport across a Type 2 boundary is the physical movement of ground water into or from the low-permeability geologic unit. The Agency recognizes that the physical and chemical processes that control fluid and solute transport through low-permeability non-aquifers is not as well understood as it is for aquifers. However, for the purposes of assessing the degree of interconnection, one must be able to infer that the flow rate of water through the non-aquifer is very small relative to the flow rates through adjacent aquifers.

The following subsections present further guidance and examples on how boundaries between ground-water units are identified.

4.3.1 General Hydrogeologic Information Needed for Identifying Ground Water Units and Analyzing Interconnection

The information required to subdivide the ground-water regime into ground-water units generally includes topics within the fields of geology, hydrology, and management of ground-water resources (controls on withdrawals/recharge, properly abandoning deep wells, etc.). The description of the ground-water regime and any potential subdivisions must be as quantitative as possible. The Agency recognizes that the degree of precision with which the Classification Review Area can be subdivided is limited by the abundance and quality of readily available data. Supplementation of the existing data base with field and laboratory investigations both on-site and off-site may be needed to accurately confirm the existence of subdivisions. The following discussion will serve to guide the types of data collection efforts needed to justify the subdivision of the Classification Review Area.

Background information on geologic formations and occurrence/movement of ground water can be obtained at a regional scale of accuracy from State and Federal agencies. Topographic maps published by the U.S. Geological Survey (USGS) are now available at useful scales for most of the nation. These can help identify ground-water flow directions and flow divides for the uppermost aquifer. Data on the distribution and characteristics of soils are available from the USDA Soil Conservation Service. General information on precipitation, run-off and recharge rates can be obtained from the USGS and can be supplemented by climatic data from weather stations around the country. Ground-water pumpage and locations/depths of wells can generally be obtained from State agencies that issue well permits, or from local Public Health Agencies and water districts.

The first step is to identify all aquifers occurring within the ground-water regime of the Classification Review Area. In areas that have been well studied these will be recognized and documented in government agency reports. In poorly studied areas, proper recognition of aquifers can be inferred from lithologic descriptions of geologic formations, structural features of the area (if flow is mainly through fractured rock), and the depth and design of wells. The areal and vertical extent of hydrogeologic units within the ground-water regime can be shown in a series of cross-sections and maps. For most hydrogeologic settings it will be most useful to interpolate between locations where conditions are known (i.e., wells, outcrops, excavations, etc.) and present variations in thickness and elevations of important units with contour maps prepared at a common scale.

After the identification and graphical representation of the geologic framework it is possible to identify ground-water units within the ground-water regime using the guidance provided in subsequent sections.

4.3.2 Type 1 Boundaries: Ground-Water Flow Divides

The concepts of ground-water flow systems may not be familiar to some readers and needs to be reviewed in order to understand flow divide boundaries between ground-water units. Figure 4-3(a) shows in vertical cross-section a series of adjacent shallow ground-water flow systems for a single-layer, water-table aquifer. The systems are bounded at the base by a physical impermeable boundary. As is typical in humid regions, the water-table profile conforms to the topographic profile.

The flow net in Figure 4-3(a) clearly shows that ground-water flow occurs from the recharge area in the highlands to the discharge areas in the lowlands (i.e., valleys). Vertical line segments AB and CD beneath the valleys and ridges constitute ground-water flow divides, i.e., imaginary impermeable boundaries across which there is no flow. In the figure, these ground-water flow divides separate adjacent flow systems ABCD and ABEF which, for purposes of subdivision, correspond to ground-water units separated by Type 1 boundaries.

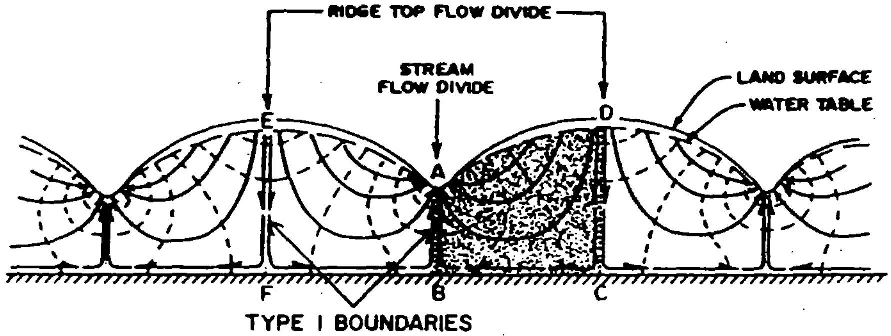
In simplified, symmetrical systems such as those illustrated in Figure 4-3(a), ground-water flow divides coincide exactly with surface water divides and extend vertically to the base of the aquifer. In more complex topographic and hydrogeologic settings these properties may diverge substantially from the situation illustrated.

A comparison of Figures 4-3(a) and 3(b) reveals how flow patterns and divides are altered when the undulations in the water table are superimposed on the regional hydraulic gradient towards a more regional stream and discharge area. Ground-water flow divides in Figure 4-3(b) extend through the full thickness of the aquifer only at either end of the entire flow regime. The full dimension of the flow regime may or may not be encompassed by the two-mile radius. The total length, S in the figures, can range from hundreds to thousands of feet.

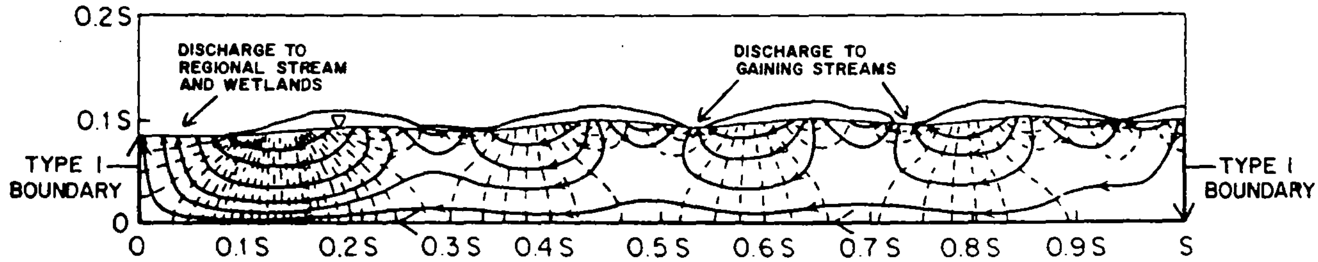
Figure 4-3(c) is an example of more complex conditions in which the flow patterns and flow systems are effected by both topography and regional variations in hydraulic conductivity of layered earth materials. Given adequate data, computerized models of real sites can provide approximations of ground-water flow patterns. In general, the level-of-sophistication employed to demonstrate the presence of a Type 1 boundary should be comensurate with the complexity of the hydrogeologic setting.

The spatial location of the water-table and ground-water flow divides may be stable under natural flow conditions but can be modified by man-made hydraulic stresses, such as large-scale ground-water withdrawals or recharge. In some cases it will be necessary to estimate the permanence (i.e., location with time) and position of ground-water flow divides under stressed conditions from available hydrologic and geologic data and foreseeable changes in water use.

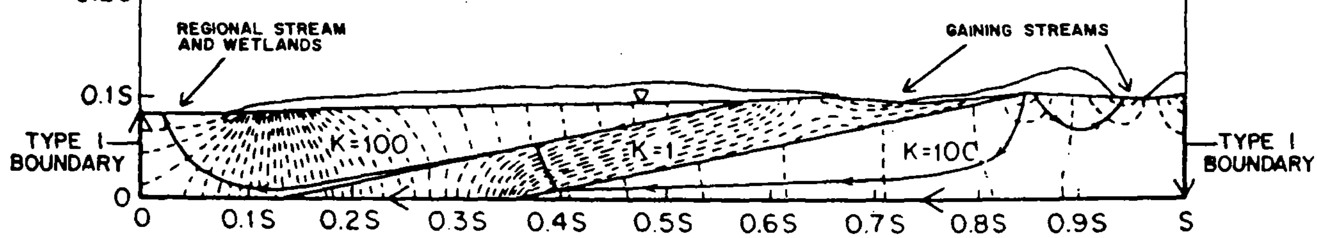
FIGURE 4-3
HYDROGEOLOGIC SECTIONS SHOWING FLOW SYSTEMS OF
INCREASING COMPLEXITY WITH TYPE 1 BOUNDARIES



a) Simple flow systems associated with a water-table aquifer (after Hubbert, 1940).



b) Ground-water flow pattern in a water-table aquifer with local and regional discharge areas (after Freeze and Whitherspoon, 1967).



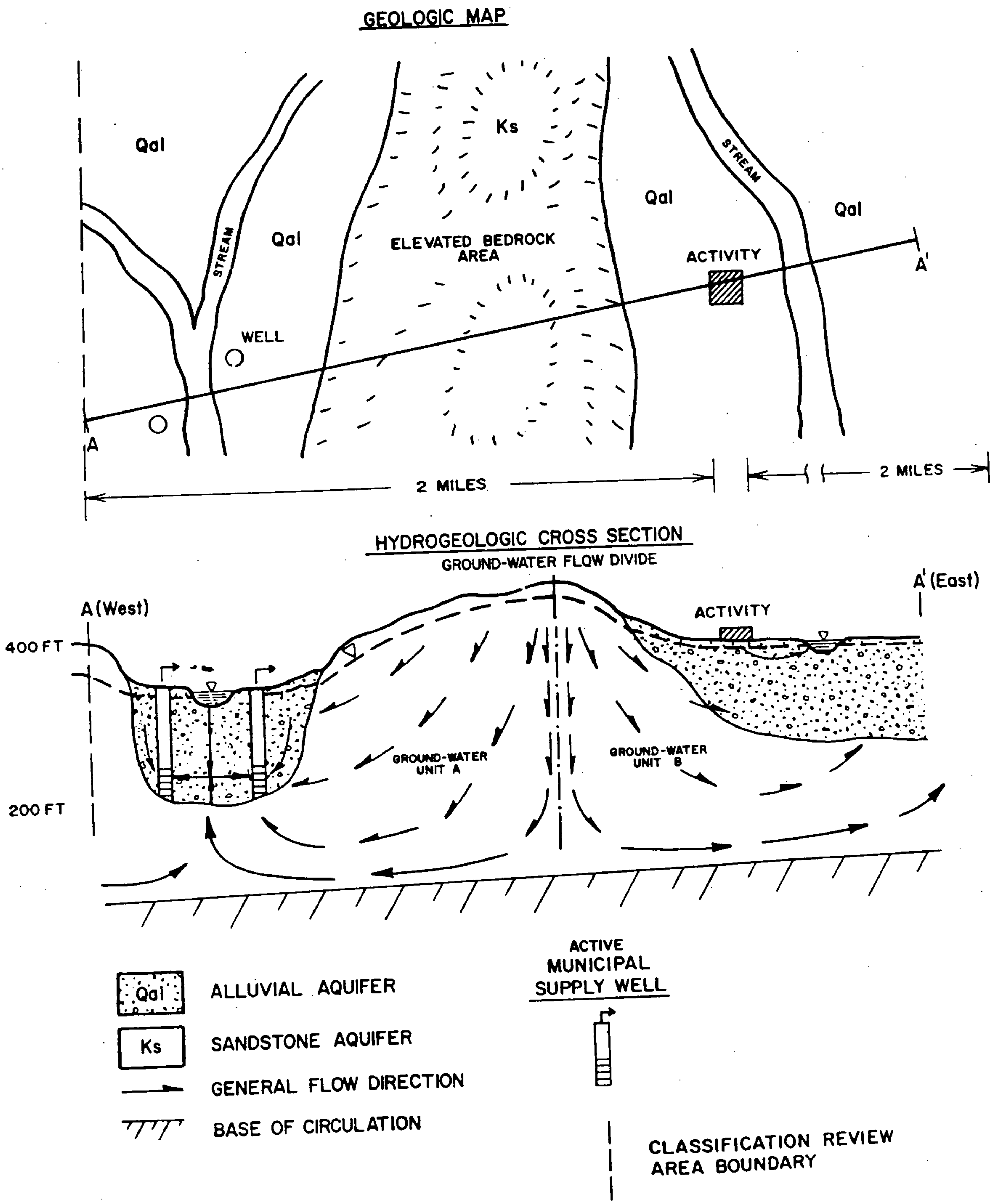
c) Ground-water flow pattern in dipping sedimentary rocks with local and regional discharge areas (after Freeze and Whitherspoon, 1967).

A good example of ground-water units separated by a Type 1 flow divide boundary is shown in Figure 4-4, The setting illustrated consists of two alluvial valleys with high-yield wells completed in sand and gravel deposits, separated by sandstone bedrock that can only provide limited supplies to domestic wells. Ground water in the alluvium is derived from precipitation and from the bedrock, and discharges to the river under natural conditions. Under pumping conditions, the water pumped by the high-yield wells is derived largely from the river, from local precipitation, and from the bedrock. Near the wells in the eastern valley, flow system boundaries are affected by ground-water withdrawals and are stable as long as the well discharges are steady. The ground-water flow divide separating the two valley aquifers is not effected by pumpage, and provides the essential characteristic that allows the delineation of ground-water units A and B.

In order to provide EPA with a defensible ground-water flow-divide delineation, a limited flow analysis will generally be required as a minimum. An acceptable approach is to prepare a water budget for the ground-water unit in order to show a reasonable order-of-magnitude balance on flow into and out of the system. This could involve the preparation of a ground-water flow net (see Glossary for definition) for the uppermost aquifer with accompanying estimates of volumetric flow into and out of the unit. The flow net can be generalized and need not be rigorously correct in a quantitative sense. The analysis should be carried out even though part of the ground-water system continues outside the Classification Review Area, that is, if part or all of the discharge or recharge area of the unit extends beyond the Classification Review Area.

The semi-quantitative flow net of the uppermost aquifer should be supplemented by a vertical hydrogeologic cross-section and supporting data showing that the uppermost aquifer is, in fact, underlain by an extensive aquitard or crystalline rock non-aquifer within the Classification Review Area. The flow net can be based on available water-table elevation data as interpreted from water levels in relatively shallow wells; locations/elevations of springs, wetlands, and perennial streams; and supplemented with topographic elevations. The rates and directions of flow can be estimated in plan view given a water-table contour map and estimates of aquifer thickness and hydraulic conductivity. The conductivity can be obtained from the area-specific reports, field or laboratory tests, or by estimating a range from the scientific literature based on earth material type. Flow patterns inferred from these data must also consider signifi-

FIGURE 4-4
EXAMPLE OF TYPE 1 FLOW DIVIDE BOUNDARY



cant spatial and directional variations in conductivity in areas having a more complex stratigraphic and structural geologic conditions.

At the beginning of the flow analysis, it is important to determine whether the ground-water flow system is in a state of steady or transient flow. Areas that are characterized by a lack of ground-water development and usage can generally be assumed to be in steady state. This will simplify the analysis because the estimate of system discharge can be equated to recharge. If the natural recharge rate compares favorably with a reasonable percentage of mean annual precipitation, the ground-water flow divides can be considered reliable. The applicant can go to the ground-water literature to obtain "reasonable" estimates to recharge in any geographic/ground-water region of the United States (e.g., see USGS Water-Supply Paper 2242 by R.C. Heath, 1984).

In areas characterized by large-scale withdrawals of ground water from shallow or deep aquifers, the flow regime is more prone to be in a transient state. Evidence of transient conditions includes:

- Declining ground-water levels
- Depletion of ground-water storage
- Movement of flow divides

When such evidence of movement exists, it may be necessary to estimate the ultimate steady-state position of the flow divides assuming conservatively large withdrawal rates and small water flow and storage properties.

4.3.3 Type 2 Boundaries: Low-Permeability Geologic Units

The Agency would assign a low degree of interconnection across the low-permeability geologic unit (Type 2 boundary) if the following conditions can be shown:

- The low-permeability geologic unit is laterally continuous beneath the entire area and/or limits the lateral continuity of the more permeable geologic unit

- There are no known wells, mine shafts, etc. that are improperly abandoned or unsealed through the geologic unit

- The geologic unit has a small permeability relative to both adjacent geologic units and to geologic media in general

- The flow of water through the geologic unit per unit area is insignificant relative to the flow of water per unit area through adjacent strata

Low-permeability geologic units include fine-grained sediments and sedimentary rocks, such as clays and shales, as well as crystalline igneous and metamorphic rocks that have few interconnecting fractures. Because these materials have small permeabilities, small quantities of water will be transmitted through them in response to hydraulic gradients. In areas where hydraulic heads beneath or within a low-permeability unit are greater than heads in an aquifer above the unit, the hydraulic gradient has an upward component across the Type 2 boundary. The Agency considers this to be the most favorable head relationship because it further ensures that the direction of ground-water movement at the boundary serves to inhibit the migration of contaminants into and across this type of boundary.

In selected environments, such as deep geologic basins, the applicant is free to make arguments that the flow of fluids is negligibly small through the low-permeability unit. The actual cut-off values of key variables such as permeability, thickness and hydraulic gradient are not specified in these guidelines and are left to professional judgments.

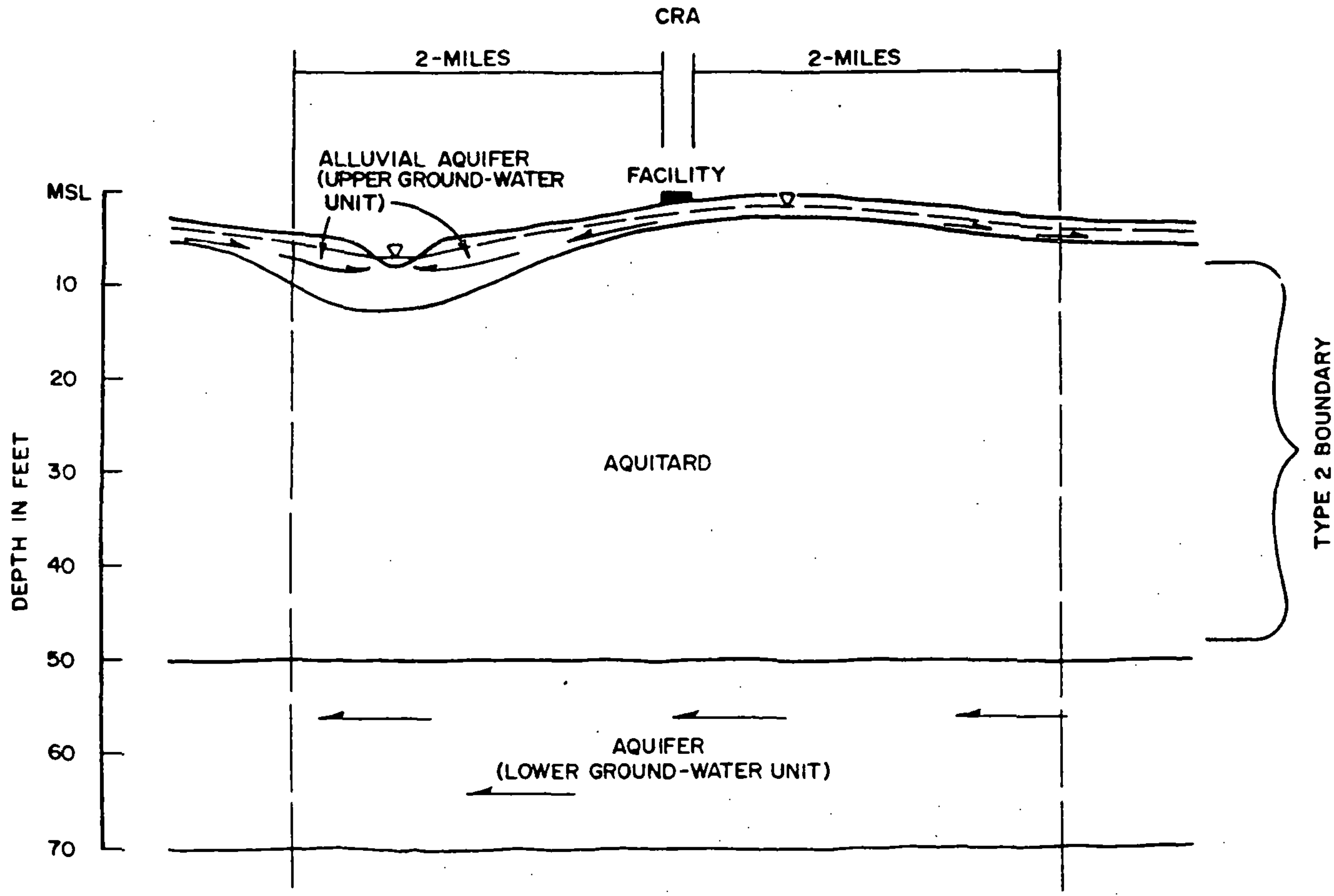
Figure 4-5 illustrates a setting where the presence of a thick, regionally extensive aquitard establishes a low degree of interconnection between a shallow ground-water unit and a deeper underlying ground-water unit (aquifer). This configuration is common in the Atlantic and Gulf coastal plain settings where the lower aquifer is the principal regional aquifer and is a source of water supply. It is overlain by an extensive confining clay that may be tens of feet thick. The shallow ground-water aquifer system supplies only limited amounts of water to wells. The reasons for the low interconnection between aquifers in this setting are as follows:

- the flow of water through the aquitard is exceedingly small,

- the time of travel of water through the aquitard is very large

Sedimentary basins commonly exhibit multiple freshwater aquifers each separated by a regionally extensive low-perme-

FIGURE 4-5
EXAMPLE OF TYPE 2 BOUNDARY



ability confining unit. Figure 4-6 is an example of such a basin where ultimate discharge of the deep fresh water through overlying low-permeability confining units (flow barriers) is to the ocean. Deeper ground waters in these basins will be characterized by a Total Dissolved Solids (TDS) concentrations that may be much greater than the 10,000 mg/l limit for Class III ground waters, and interconnection is considered to be low, even though hydraulic gradients are in the direction of less saline water.

The reasons for the low degree of interconnection are as follows:

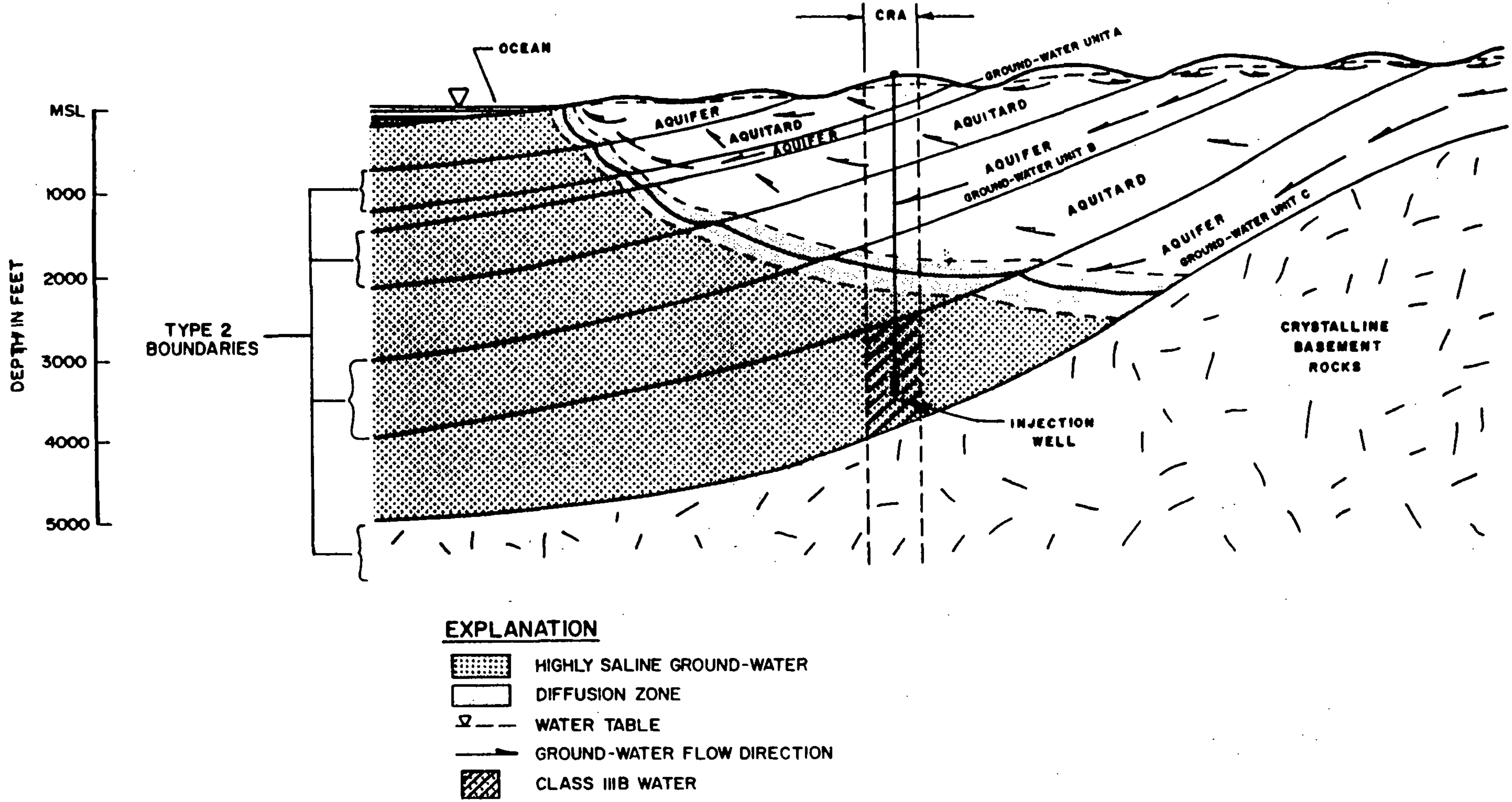
- salts are retained in deep aquifers confined by laterally extensive aquitards,
- the flow of water through the confining units is exceedingly small,
- the time of travel through the confining unit is very large
- the depth to these waters is generally below the bottom of any major water-supply wells in the area.

Deep, confined, saline ground-water units with a low degree of interconnection to overlying fresh ground-water units are currently the primary hydrogeologic setting into which wells can be permitted to inject hazardous wastes under present EPA and state Underground Injection Control (UIC) regulations. These waters are herein defined as Class III, Subclass B ground water. EPA's position is that the interconnection test for such candidate Class IIIB waters will follow those tests for the UIC program, Class I wells.

In general, the demonstration of the existence of a Type 2 boundary requires that one identify and characterize the laterally continuous low-permeability non-aquifer that constitutes the boundary. The following is a list of factors to be considered in making this demonstration:

- Stratigraphic setting and lithologic characteristics
- Structural setting and joint/fracture/fault characteristics
- Hydrogeologic setting and hydraulic head/fluid flow characteristics

FIGURE 4-6
EXAMPLE OF TYPE 2 BOUNDARIES BETWEEN AQUIFERS IN A SEDIMENTARY BASIN



The first distinction should be between whether the non-aquifer is of sedimentary or igneous/metamorphic origin. If it is sedimentary in origin, an identification of the environment of deposition will permit inferences about the expected geometry, thickness, and continuity of individual strata. These inferences should be defended with geologic sections including data from well logs and/or measured sections. The age of the unit, the degree of cementation, and degree of compaction are all qualitatively related to water-bearing characteristics (hydraulic conductivity and porosity).

If the unit is an igneous or metamorphic rock, the continuity and thickness can usually be inferred from geologic maps and reports for the region in which the Classification Review Area exists. Identification of igneous rocks that have tabular geometries such as volcanic flows, ash-fall deposits, or intrusive sills and dikes will allow inferences about thickness and continuity. These may serve as aquifers or aquitards within a sequence of sedimentary rocks. Crystalline "basement" rocks of igneous and metamorphic origin underlie the entire North American continent. In areas where these rocks are fractured and exposed at or near the land surface, they generally serve as poor-yielding aquifers. However, significant circulation can be assumed to be restricted to the upper few hundred feet because the fractures tend to close with depth. In other areas, where these rocks are buried by younger rocks, they can generally be assumed to represent the base of active circulation unless there is evidence to the contrary. In these situations the Type 2 boundary is equivalent to the bottom of the ground-water regime (see Glossary).

A general knowledge of the tectonic setting and structural geologic history of the region will provide insight into the types and frequency of geologic structures to be found in the Classification Review Area. Numerous field studies have shown that significant ground-water flow in consolidated sedimentary and crystalline rocks is controlled by geologic structures. These features include folds, faults and associated joints and fractures in the rock.

Major structures such as fault zones that intersect consolidated rock formations may hydraulically connect multiple aquifers into a system of aquifers. Fault zones in consolidated rocks are known to collect water from large areas and control the locations of ground-water discharge at major springs. In softer sediments and in some structural settings, fault zones can have the opposite effect by producing barriers to flow. Individual joints and small fractures in consolidated rocks and sediment can be mapped systematically with field studies, however, proof of their absence is the more important element in demonstrating the presence of a Type 2 boundary.

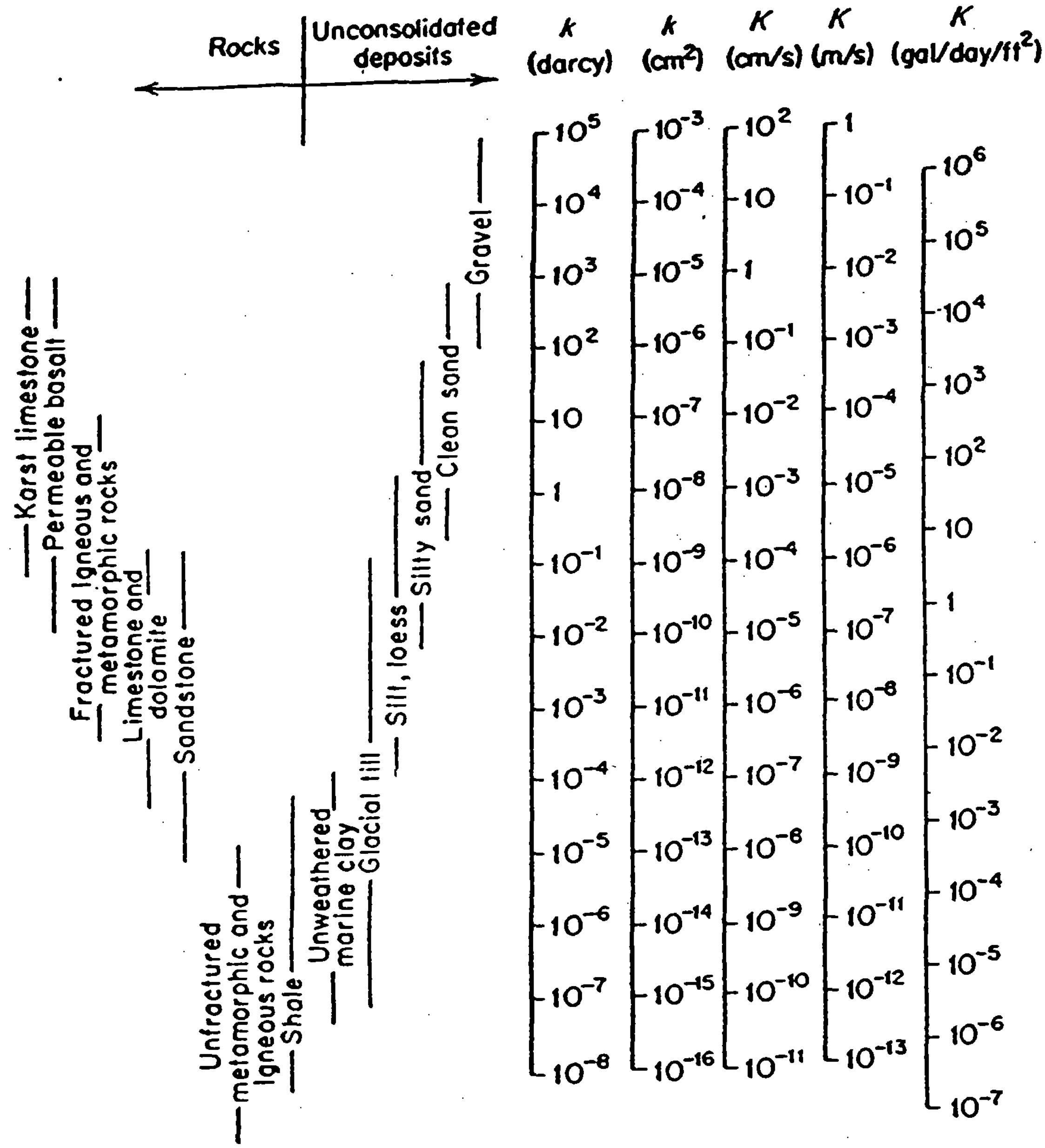
The best evidence of low-permeability non-aquifer conditions constituting a Type 2 boundary are those related to the hydrogeologic setting and measured hydraulic parameters. Table 4-2 shows that the hydraulic conductivity of both sedimentary deposits and igneous/metamorphic rocks can be estimated within several orders-of-magnitude on the basis of lithology alone. In parts of the United States associated with large ground-water usage, there has been a need to understand the ground-water regime and these areas will often have been studied by various government agencies. Consequently, the hydraulic properties of aquifers and aquitards will be known in quantitative terms. In these areas the thickness, lateral extent, and hydraulic conductivity will be documented. A favorable condition would then be associated with a recognized aquitard or aquiclude that is known to be relatively thick, homogeneous, widespread, and poorly permeable. The optimum head condition would be such that vertical hydraulic gradients are directed upward through the unit, i.e., across the Type 2 boundary.

4.3.4 Type 3 Boundaries: Fresh/Saline Water Contacts

Type 3 boundaries between bodies of ground water with contrasting concentrations of Total Dissolved Solids (TDS) most commonly occur within the following types of hydrogeologic settings:

- Sea-water intrusion into fresh-water aquifers in coastal regions,
- Saline waters associated with ancient evaporite deposits in sedimentary basins,
- Saline waters associated with closed topographic basins in arid regions.
- Saline brines in deep geologic basins,
- Geothermal fluids in tectonically active regions,

TABLE 4-2
RANGE OF VALUES OF HYDRAULIC CONDUCTIVITY AND PERMEABILITY
(AFTER FREEZE AND CHERRY, 1979)



In the above settings, the TDS of naturally occurring saline water may be 3 to 10 times greater than the 10,000 mg/l criterion. Owing to natural concentration gradients, a zone of diffusion is normally observable between the saline and fresh ground waters. The 10,000 mg/l TDS isometric surface will generally be situated within the diffusion zone separating the waters of contrasting salinities.

Figure 4-7 illustrates how a wedge of sea water which has intruded into an unconfined aquifer is identified as a separate ground-water unit of higher salinity and density relative to an adjacent ground-water unit, in the same aquifer, containing fresh water. In this setting, there exists a zone of diffusion between two flow systems that contain fresh water and sea water. The salinity boundary would occur along the 10,000 mg/l TDS isometric surface.

Figure 4-8 illustrates a second hydrogeologic setting characterized by the presence of near-surface evaporite deposits overlying deeper bedrock units. Salts are dissolved from the evaporite units by the circulating ground waters and a shallow zone of saline waters coexists with fresh ground waters within the same flow system. However, based on the delineation of a Type 3 boundary, two distinct ground-water units can be identified.

Although the saline water is primarily confined to the low-permeability evaporite formation, this water leaks into the underlying aquifer creating a zone of diffusion within the underlying aquifer. The boundary between the two adjacent ground-water units would be drawn along the 10,000 mg/l TDS isometric surface within the diffusion zone. The diffusion zone would be a stable feature assuming the flow system is in both hydraulic and geochemical steady state. The degree of interconnection between these adjacent ground-water units is defined to be intermediate. The type of setting illustrated in Figure 4-8 is not as common as the coastal intrusion setting illustrated in Figure 4-7, but it is known to exist in selected parts of the United States.

In the above two settings, the intermediate degree of interconnection between ground-water units is due to the limited potential for the exchange of waters across a Type 3 boundary within a diffusion zone. In the first setting, the salt water and fresh water are in separate, but adjacent flow systems. In the second case, the diffusion zone is more extensive and may or may not be within a single flow system. A third case involves a single regional flow system with the diffusion zone in the deeper and more downgradient end of the system.

FIGURE 4-7
EXAMPLE OF TYPE 3 BOUNDARY THROUGH AN
UNCONFINED AQUIFER IN A COASTAL SETTING

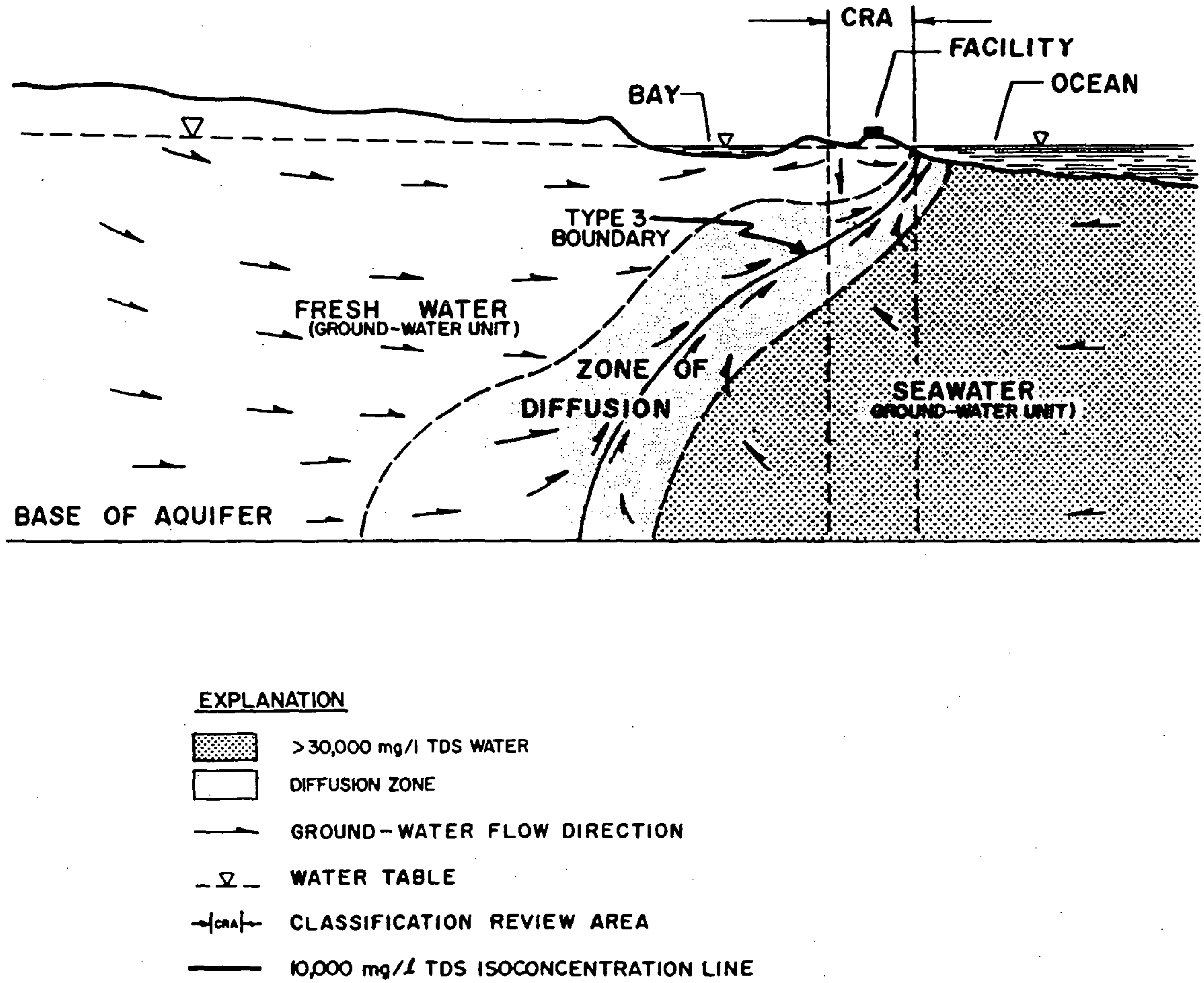
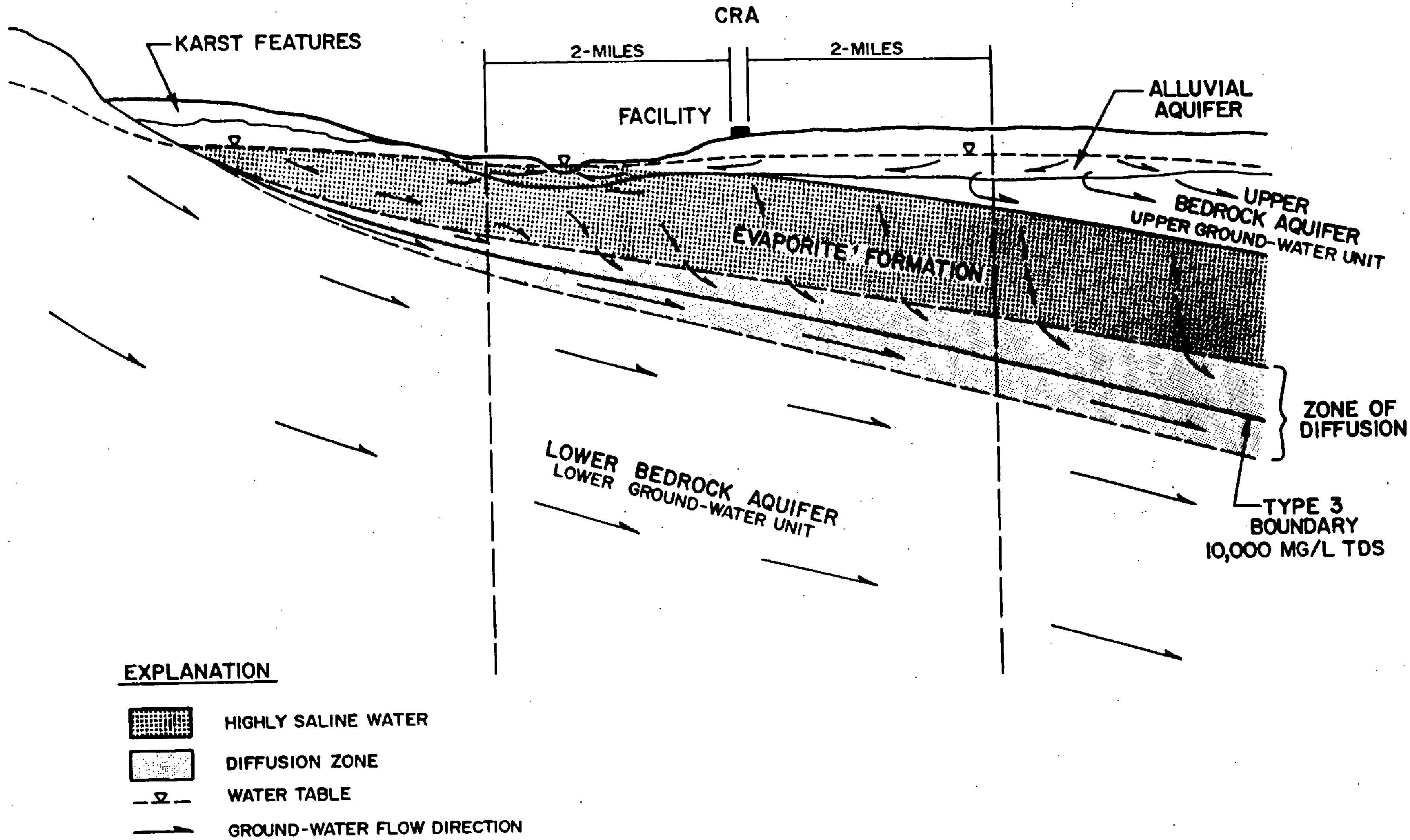


FIGURE 4-8
EXAMPLE OF TYPE 3 BOUNDARY IN AN EVAPORITE/SALINE WATER SETTING



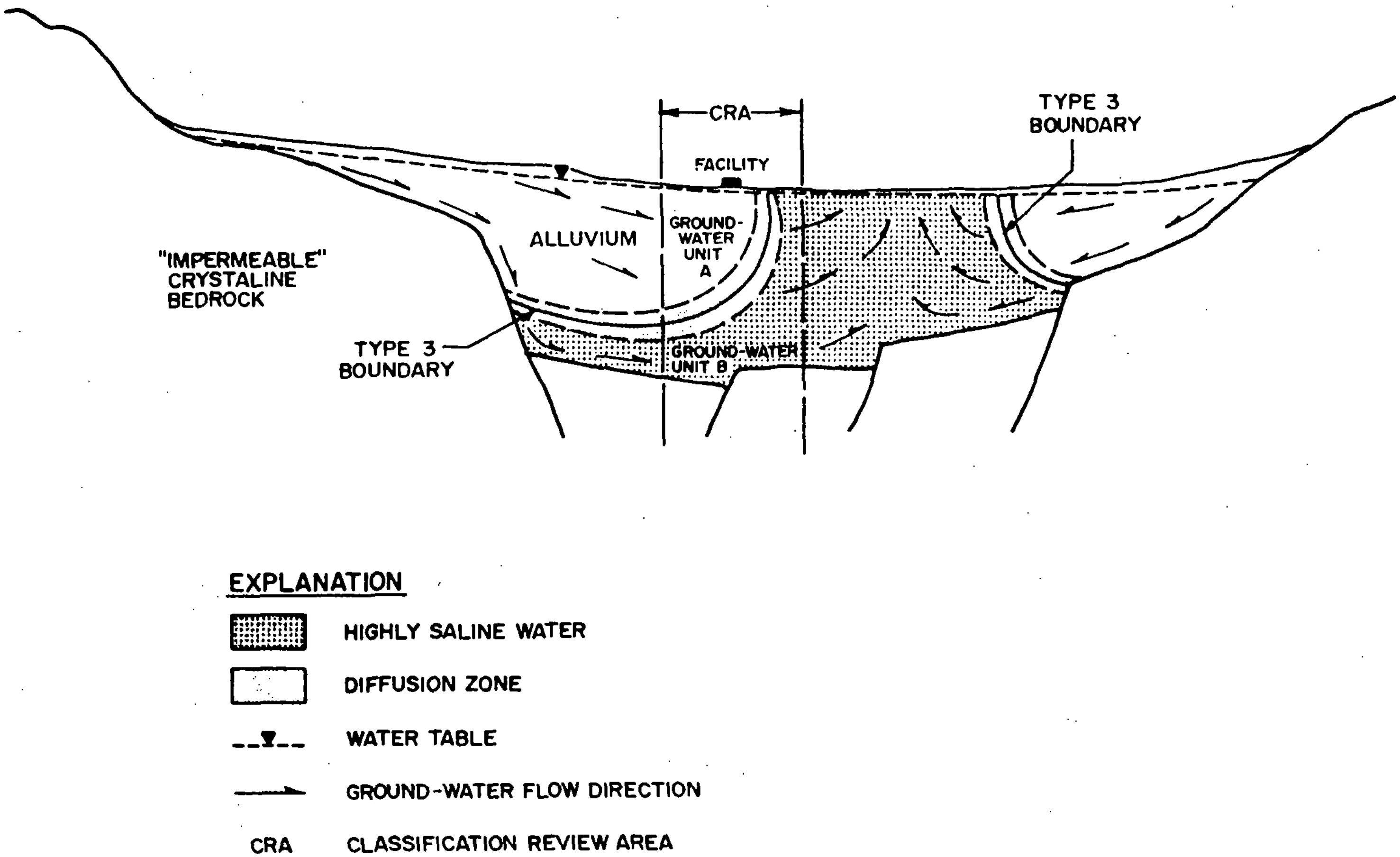
The third setting includes naturally saline ground water contained within topographically-closed structural basins within arid parts of the western United States (e.g., the Great Salt Lake Desert). Figure 4-9 shows an example of such a setting where the water is recharged from runoff from mountain ranges adjoining the basin, circulates to the center of the basin, moves vertically through confining beds, and discharges to playa lakes and the atmosphere. These settings are known to have brine waters greatly in excess of the 10,000 mg/l Class III criteria within the discharge area to depths as great as 2000 feet below land surface.

Distinct ground-water units can be delineated based on the identification of Type 3 boundaries as shown in Figure 4-9. Under natural conditions the diffusion zones encompassing these boundaries are stable and ground-water units A and B can be identified as shown. Large-scale withdrawals from upgradient fresh (Class II) ground water or injection into the saline (Class III) ground-water can laterally displace the diffusion zone. The pumped wells may eventually yield saline water and will cease to be sources of drinking water. Thus, the potential to cause adverse water-quality effects may result from improper resource management.

Type 3 boundaries are the least interpretive of the boundary types because they are simply equivalent to the 10,000 mg/l TDS isometric surface through the ground-water regime. These boundaries are then easily recognized and mapped when TDS data are available for ground waters from various depths and locations in the Classification Review Area. The elevations at which ground-water TDS is equal to or greater than 10,000 mg/l has been mapped and published for selected basins and regions. The principal sources for such data are the USGS and state geological surveys, especially in states having abundant oil and gas resources. In areas of known sea-water intrusion, or upconing of salt water due to pumpage, published data are occasionally available which will show in vertical section or plan view the extent of the salt-water wedge. This may be conservatively taken as the 10,000 mg/l TDS boundary where more specific TDS data are not available. In areas of known high temperature geothermal resources, published data are available to estimate the Type 3 boundary location. Because these areas, are few in number and are limited in areal extent, few will be co-located with potential Classification Review Areas. Equally limited are data bases for saline water settings associated with soluble evaporite deposits. At specific sites in these areas, the relationship between water quality, soluble strata, and ground-water flow directions can be established and the Type 3 boundary mapped. This relationship can be assumed in

FIGURE 4-9

EXAMPLE OF TYPE 3 BOUNDARY THROUGH BASIN FILL IN A CLOSED BASIN/ARID CLIMATIC SETTING



REFERENCE 25

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV

345 COURTLAND STREET, N.E.
ATLANTA, GEORGIA 30365

JUN 03 1993

4WD-WPB

Mr. Jim McCarthy
Florida Department of Environmental Regulation
Twin Tower Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Dear Mr. McCarthy:

As per our conversation on June 3, 1993, the Environmental Protection Agency (EPA) is requesting your assistance in confirming surficial aquifer usability in Orlando, Florida. I have enclosed a copy of the Water Resources of Orange County, Florida and a copy of the classification letter developed by Ground Water Division at EPA.

Please confirm the State of Florida's method of aquifer classification in written form. It would also be helpful if you send a copy of the pages used to determine aquifer usability from the state's guidance.

If you have any questions, please do not hesitate to call me at (404) 347-5065. EPA would appreciate your promptness in responding to this letter.

Sincerely,

Cynthia K. Gurley

Cynthia K. Gurley
Site Assessment Manager
South Florida

Florida Department of Environmental Regulation

Twin Towers Office Bldg. • 2600 Blair Stone Road • Tallahassee, Florida 32399-2400

Lawton Chiles, Governor

Virginia B. Wetherell, Secretary

June 4, 1993

U.S. Environmental Protection
Agency
345 Courtland Street, N.E.
Atlanta, Georgia 30365
Attention: Ms. Cindy Gurley
Site Assessment Manager

Re: **Chevron Chemical; Co., Ortho. Div.-Orlando and Surficial Aquifer System Groundwater Classification.**

Dear Ms. Gurley:

I have reviewed some groundwater analyses of surficial aquifer system wells in the St. Johns and South Florida Water Management District VISA networks. Unfortunately, there is no water quality data in the immediate vicinity of the Chevron Chemical site and the review is based on regional data. FDER has established Groundwater Classifications based on Total Dissolved Solids (TDS) under FAC 17-520. TDS values in surficial aquifer system wells in South Orange County range from 46-382 mg/L. Based on FDER FAC 17-520.410, the surficial aquifer system in this region would qualify as Class G-II aquifer (Potable Water Use [not a single source aquifer], groundwater in aquifer has TDS less than 10,000 mg/L). I have enclosed documentation of the analyses and the FDER rule with this letter.

I hope this information is adequate for HRS scoring purposes. If not, please contact Mr. Don Boniol of the St. Johns Water Management District for additional information at 904-329-4188.

Sincerely,

A. James McCarthy Jr., P.G.
P.G No. 1355
Professional Geologist I
Bureau of Waste Cleanup
Site Screening Superfund
Subsection

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****************************************************
** DATA MARKED "PROV" IS PROVISIONAL DATA
** AND IS SUBJECT TO CHANGE -- DO NOT RELEASE
** OR USE FOR OFFICIAL WORK!
****************************************************
-- 282608081221601     282608     812216     7       7      SF MR-0004
 42 850710  SULFATE,TOTAL                          4.0000  mg/l
 42 860624  SULFATE,TOTAL                         10.7000  mg/l
 46 850710  CHLORIDE,TOTAL                         1.9000  mg/l
 46 860624  CHLORIDE,TOTAL                         8.2000  mg/l
328 850710  TOTAL DISSOLVED SOLIDS                90.0000  mg/l
328 860624  TOTAL DISSOLVED SOLIDS                73.1000  mg/l
-- 282353081313701     282353     813137     18      18     SF OR-0003
 42 850710  SULFATE,TOTAL                         54.3000  mg/l
 42 860624  SULFATE,TOTAL                         38.5000  mg/l
 42 870623  SULFATE,TOTAL                         26.1000  mg/l
 42 880908  SULFATE,TOTAL                         23.0000  mg/l
 42 890321  SULFATE,TOTAL                         25.6000  mg/l
 42 890612  SULFATE,TOTAL                         28.7000  mg/l
 42 890807  SULFATE,TOTAL                         23.5000  mg/l
 42 891016  SULFATE,TOTAL                         34.4000  mg/l
 42 900119  SULFATE,TOTAL                         46.6000  mg/l
 42 900412  SULFATE,TOTAL                         29.8000  mg/l
 42 900710  SULFATE,TOTAL                         37.1000  mg/l
 46 850710  CHLORIDE,TOTAL                        29.2000  mg/l
 46 860624  CHLORIDE,TOTAL                        20.1000  mg/l
 46 870623  CHLORIDE,TOTAL                        30.0000  mg/l
 46 880908  CHLORIDE,TOTAL                        29.0000  mg/l
 46 890321  CHLORIDE,TOTAL                        36.6000  mg/l
 46 890612  CHLORIDE,TOTAL                        30.8000  mg/l
 46 890807  CHLORIDE,TOTAL                        42.8000  mg/l
 46 891016  CHLORIDE,TOTAL                        36.7000  mg/l
 46 900119  CHLORIDE,TOTAL                        37.7000  mg/l
 46 900412  CHLORIDE,TOTAL                        58.9000  mg/l
 46 900710  CHLORIDE,TOTAL                        69.8000  mg/l
328 850710  TOTAL DISSOLVED SOLIDS               299.0000  mg/l
328 860624  TOTAL DISSOLVED SOLIDS               176.1000  mg/l
328 870623  TOTAL DISSOLVED SOLIDS               157.9000  mg/l
328 880908  TOTAL DISSOLVED SOLIDS               159.0000  mg/l
328 890321  TOTAL DISSOLVED SOLIDS               177.9000  mg/l
328 890612  TOTAL DISSOLVED SOLIDS               193.9000  mg/l
328 890807  TOTAL DISSOLVED SOLIDS               211.9000  mg/l
328 891016  TOTAL DISSOLVED SOLIDS               222.0000  mg/l
328 900119  TOTAL DISSOLVED SOLIDS               219.1000  mg/l
328 900412  TOTAL DISSOLVED SOLIDS               242.9000  mg/l
328 900710  TOTAL DISSOLVED SOLIDS               309.9000  mg/l
 40 900920  SULFATE,DISSOLVED                     71.0000  mg/l      PROV
 44 900920  CHLORIDE,DISSOLVED IN WATER           69.0000  mg/l      PROV
328 900920  TOTAL DISSOLVED SOLIDS               382.0000  mg/l      PROV
-- 282257081383201     282257     813832     83      0      SF OR-0004
 42 850710  SULFATE,TOTAL                          3.7000  mg/l
 42 860624  SULFATE,TOTAL                          3.3000  mg/l
 42 870623  SULFATE,TOTAL                   <      5.0000  mg/l
 46 850710  CHLORIDE,TOTAL                         2.8000  mg/l
 46 860624  CHLORIDE,TOTAL                         5.5000  mg/l
 46 870623  CHLORIDE,TOTAL                         6.7000  mg/l
328 850710  TOTAL DISSOLVED SOLIDS               161.0000  mg/l
328 860624  TOTAL DISSOLVED SOLIDS               166.0000  mg/l
328 870623  TOTAL DISSOLVED SOLIDS               161.0000  mg/l
328 890124  TOTAL DISSOLVED SOLIDS               123.9000  mg/l
-- 282241081112802     282241     811128     29      26     SF OR-0010
 42 850710  SULFATE,TOTAL                          6.8000  mg/l
 42 860624  SULFATE,TOTAL                          8.2000  mg/l
 42 870624  SULFATE,TOTAL                   <      5.0000  mg/l
 42 880628  SULFATE,TOTAL                   <      2.0000  mg/l
 42 891016  SULFATE,TOTAL                   <      2.0000  mg/l
 42 900119  SULFATE,TOTAL                   <      2.0000  mg/l
 42 900412  SULFATE,TOTAL                   <      2.0000  mg/l
 42 900710  SULFATE,TOTAL                   <      2.0000  mg/l
 42 901017  SULFATE,TOTAL                   <      2.0000  mg/l
 46 850710  CHLORIDE,TOTAL                        35.3000  mg/l
 46 860624  CHLORIDE,TOTAL                        36.5000  mg/l
```

46	870624	CHLORIDE,TOTAL			38.0000	mg/l	
46	880628	CHLORIDE,TOTAL			40.0000	mg/l	
46	891016	CHLORIDE,TOTAL			45.2000	mg/l	
46	900119	CHLORIDE,TOTAL			45.2000	mg/l	
46	900412	CHLORIDE,TOTAL			46.1000	mg/l	
46	900710	CHLORIDE,TOTAL			48.8000	mg/l	
46	901017	CHLORIDE,TOTAL			46.2000	mg/l	
328	850710	TOTAL DISSOLVED SOLIDS			56.9000	mg/l	
328	860624	TOTAL DISSOLVED SOLIDS			178.0000	mg/l	
328	870624	TOTAL DISSOLVED SOLIDS			119.9000	mg/l	
328	880628	TOTAL DISSOLVED SOLIDS			175.9000	mg/l	
328	890124	TOTAL DISSOLVED SOLIDS			150.0000	mg/l	
328	891016	TOTAL DISSOLVED SOLIDS			159.0000	mg/l	
328	900119	TOTAL DISSOLVED SOLIDS			170.0000	mg/l	
328	900412	TOTAL DISSOLVED SOLIDS			139.9000	mg/l	
328	901017	TOTAL DISSOLVED SOLIDS			123.1000	mg/l	
--	282456081241601	282456	812416	28	18	SF OV-01S	
40	900925	SULFATE,DISSOLVED			24.0000	mg/l	PROV
44	900925	CHLORIDE,DISSOLVED IN WATER			21.0000	mg/l	PROV
328	900925	TOTAL DISSOLVED SOLIDS			94.0000	mg/l	PROV
--	282537081241701	282537	812417	28	18	SF OV-02S	
40	900920	SULFATE,DISSOLVED			1.3000	mg/l	PROV
44	900920	CHLORIDE,DISSOLVED IN WATER			69.0000	mg/l	PROV
328	900920	TOTAL DISSOLVED SOLIDS			225.0000	mg/l	PROV
--	282544081221301	282544	812213	15	14	SF OV-03S	
40	900925	SULFATE,DISSOLVED			7.1000	mg/l	PROV
44	900925	CHLORIDE,DISSOLVED IN WATER			34.0000	mg/l	PROV
328	900925	TOTAL DISSOLVED SOLIDS			114.0000	mg/l	PROV
--	282342081222301	282342	812223	15	5	SF OV-04	
40	900925	SULFATE,DISSOLVED			14.0000	mg/l	PROV
44	900925	CHLORIDE,DISSOLVED IN WATER			5.1000	mg/l	PROV
328	900925	TOTAL DISSOLVED SOLIDS			66.0000	mg/l	PROV
--	282336081210401	282336	812104	16	6	SF OV-05	
40	900925	SULFATE,DISSOLVED			6.2000	mg/l	PROV
44	900925	CHLORIDE,DISSOLVED IN WATER			12.0000	mg/l	PROV
328	900925	TOTAL DISSOLVED SOLIDS			54.0000	mg/l	PROV
--	282333081200901	282333	812009	16	6	SF OV-06	
40	900925	SULFATE,DISSOLVED			9.5000	mg/l	PROV
44	900925	CHLORIDE,DISSOLVED IN WATER			4.1000	mg/l	PROV
328	900925	TOTAL DISSOLVED SOLIDS			52.0000	mg/l	PROV
--	282401081224501	282401	812245	19	9	SF OV-07A	
40	900919	SULFATE,DISSOLVED			32.0000	mg/l	PROV
40	900925	SULFATE,DISSOLVED			6.8000	mg/l	PROV
44	900919	CHLORIDE,DISSOLVED IN WATER			7.7000	mg/l	PROV
44	900925	CHLORIDE,DISSOLVED IN WATER			7.0000	mg/l	PROV
328	900919	TOTAL DISSOLVED SOLIDS			71.0000	mg/l	PROV
328	900925	TOTAL DISSOLVED SOLIDS			46.0000	mg/l	PROV

(b) Are carcinogenic, mutagenic, teratogenic, or toxic to human beings, unless specific criteria are established for such components in Rule 17-520.420, F.A.C.; or

(c) Are acutely toxic to indigenous species of significance to the aquatic community within surface waters affected by the ground water at the point of contact with surface waters; or

(d) Pose a serious danger to the public health, safety, or welfare; or

(e) Create or constitute a nuisance; or

(f) Impair the reasonable and beneficial use of adjacent waters.

(2) The minimum criteria shall not apply to Class G-IV ground water, unless the Department determines there is a danger to the public health, safety or welfare.

(3) The following procedures shall apply in the implementation of (1)(b) above:

(a) The Secretary is authorized to make determinations, in individual permitting or enforcement proceedings, that a particular level for a substance is a prohibited concentration in violation of a minimum criterion pursuant to (1)(b) above. This determination may not be delegated to Department districts.

(b) Any notice of proposed agency action published pursuant to Rule 17-103.150, F.A.C., which contains such a determination shall include notification of the particular substance and prohibited concentration level being proposed. The notice shall be submitted to the Florida Administrative Weekly at the time it is sent to the permit applicant for publication.

(c) The Department shall notify the Commission semiannually of every application of a determination to a discharger made by the Secretary during the preceding six months pursuant to (a) above for any constituent and concentration level not adopted by the Commission as a rule. The notification shall identify the discharger(s) to whom the application of a determination has been made, the type of industry, the constituent and concentration level set and a summary of the basis for the determination. At the written request of the Commission or any substantially affected member of the public, the Department shall, within 120 days of the written request, submit to the Florida Administrative Weekly a notice of rulemaking pursuant to Section 120.54(1), F.S., on the determination for the particular constituent and concentration level that is the subject of a notification in the preceding sentence.

(d) The application of the determination under paragraph (a) to the permittee or to other affected dischargers shall be subject to:

1. Modification where necessary to conform to any final rulemaking action of the Commission under (c) above; or

2. Withdrawal if the Commission elects not to adopt a corresponding rule after initiation of rulemaking for the constituent under (c) above.

(e) The notice procedures contained in subsection (3) shall not act as a stay of Department enforcement proceedings.

(f) Once a particular standard for a criterion is established by the Commission, it shall be listed in this section.

Specific Authority: 403.061, F.S.
Law Implemented: 403.021, 403.061, F.S.
History: Formerly 17-3.051, Amended and Renumbered 1-1-83, Formerly 17-3.402, Amended 9-8-92.

17-520.410 Classification of Ground Water, Usage, Reclassification.

(1) All ground water of the State is classified according to designated uses as follows:

Class F-I	Potable water use, ground water in a single source aquifer described in Rule 17-520.460, F.A.C. which has a total dissolved solids content of less than 3,000 mg/l and was specifically reclassified as Class F-I by the Commission.
Class G-I	Potable water use, ground water in single source aquifers which has a total dissolved solids content of less than 3,000 mg/l.
Class G-II	Potable water use, ground water in aquifers which has a total dissolved solids content of less than 10,000 mg/l, unless otherwise classified by the Commission.
Class G-III	Non-potable water use, ground water in unconfined aquifers which has a total dissolved solids content of 10,000 mg/l or greater; or which has total dissolved solids of 3,000-10,000 mg/l and either has been reclassified by the Commission as having no reasonable potential as a future source of drinking water, or has been designated by the Department as an exempted aquifer pursuant to Rule 17-28.130(3), F.A.C.

(12) "Pollution" means the presence in the outdoor atmosphere or waters of the state of any substances, contaminants, noise, or man-made or man-induced alteration of the chemical, physical, biological or radiological integrity of air or water in quantities or levels which are or may be potentially harmful or injurious to human health or welfare, animal or plant life, or property, including outdoor recreation.

(13) "Secretary" means the Secretary of the Department.

(14) "Single Source Aquifer" means an aquifer or a portion of an aquifer which, pursuant to Rule 17-520.410(5) and (6), F.A.C., is determined by the Commission to be the only reasonably available source of potable water to a significant segment of the population.

(15) "Site" means the area within an installation's property boundary where effluents are released or applied to the ground water.

(16) "Surface Water" means water upon the surface of the earth, whether contained in bounds created naturally or artificially or diffused. Water from natural springs shall be classified as surface water when it exits from the spring onto the earth's surface.

(17) "Unconfined Aquifer" means an aquifer other than a confined aquifer.

(18) "Waters" include, but are not limited to, rivers, lakes, streams, springs, impoundments, and all other waters or bodies of water, including fresh, brackish, saline, tidal, surface or underground waters. Waters owned entirely by one person other than the state are included only in regard to possible discharge on other property or water. Underground waters include, but are not limited to, all underground waters passing through pores of rock or soils or flowing through in channels, whether manmade or natural.

(19) "Zone of Discharge" means a volume underlying or surrounding the site and extending to the base of a specifically designated aquifer or aquifers, within which an opportunity for the treatment, mixture or dispersion of wastes into receiving ground water is afforded.

(20) "Zone of Saturation" means a subsurface zone in which all of the interstices are filled with water.

Specific Authority: 403.061, F.S.
Law Implemented: 403.021, 403.031, 403.061, F.S.
History: New 9-8-92.

17-520.300 General Provisions for Ground Water Classes, Standards, and Exemptions.

(1) This Chapter contains criteria which are applicable to ground water.

17-520.200(12) - 17-520.300(1)

(2) To determine if the ground water criteria in this Chapter are being met, ground water quality shall be monitored in accordance with this rule and Chapter 17-522, F.A.C.

(3) A violation of any ground water criterion contained in this Chapter constitutes pollution.

(4) In addition to any technology-based effluent limitations required by Department rule, the Department shall also specify water quality-based effluent limitations when necessary to assure that the water quality criteria will be met.

(5) Notwithstanding the classification and criteria for ground water set forth in this Chapter, discharge to ground water shall not impair the designated use of contiguous surface waters.

(6) Compliance with ground water standards shall be determined by analyses of unfiltered ground water samples, unless a filtered sample is as or more representative of the particular ground water quality.

(7) For owners of installations having filed a complete application for a Chapter 403, F.S., permit covering water discharges as of January 1, 1983, or discharging pollutants to ground water as of July 1, 1982, compliance with the minimum criteria set forth in Rule 17-520.400, F.A.C., shall be determined by analysis of the constituents of the waste stream of the installation causing the discharge; provided, however, that the installation owner may, at his option, place a monitoring well immediately outside the site boundary to measure compliance with the minimum criteria, as long as the discharge poses no danger to the public health, safety or welfare.

Specific Authority: 403.061, 403.087, F.S.
Law Implemented: 403.021, 403.061, 403.087, 403.088, 403.502, 403.702, F.S.
History: Formerly 17-3.071, Amended and Renumbered 1-1-83, Formerly 17-3.401, Amended 9-8-92.

17-520.400 Minimum Criteria for Ground Water.

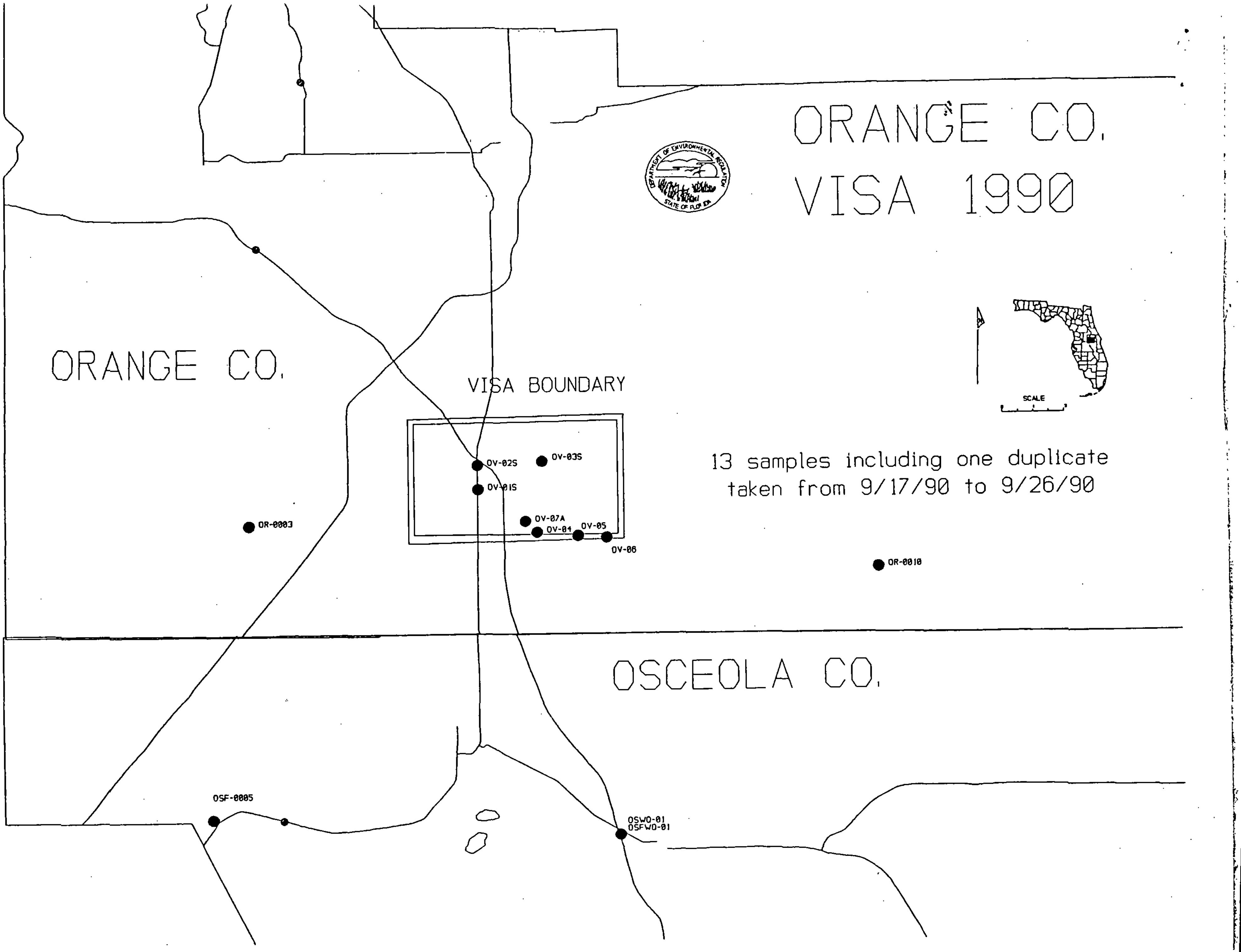
(1) All ground water shall at all places and at all times be free from domestic, industrial, agricultural, or other man-induced non-thermal components of discharges in concentrations which, alone or in combination with other substances, or components of discharges (whether thermal or non-thermal):

(a) Are harmful to plants, animals, or organisms that are native to the soil and responsible for treatment or stabilization of the discharge relied upon by Department permits; or

17-520.300(2) - 17-520.400(1)(a)

Positive Findings, Orange County VISA, Page 1.

Sample	Sample Date	Parameter, Value
OV-01S	9/18/90	Iron, 0.981 mg/L
OV-02S	9/20/90	Iron, 3.470 mg/L
OV-03S	9/17/90	Iron, 4.620 mg/L
OV-04	9/18/90	Iron, 0.970 mg/L
OV-05	9/18/90	Iron, 1.560 mg/L
OV-06	9/18/90	Iron, 1.130 mg/L
OR-0010	9/18/90	Iron, 0.724 mg/L
OSWQ-01	9/19/90	Iron, 1.250 mg/L Manganese, 0.051 mg/L
OSWQ-02	9/19/90	Iron, 1.290 mg/L Manganese, 0.052 mg/L


ORANGE CO.
VISA 1990
ORANGE CO.
VISA BOUNDARY
OV-02S
OV-03S
OV-01S
OV-07A
OV-04
OV-05
OV-06
OR-0003
OR-0010
13 samples including one duplicate taken from 9/17/90 to 9/26/90
SCALE
OSCEOLA CO.
OSF-0005
OSWO-01
OSFWO-01

STATE OF FLORIDA

DEPARTMENT OF NATURAL RESOURCES
Virginia B. Wetherell, Executive Director

DIVISION OF RESOURCE MANAGEMENT
Jeremy Craft, Director

FLORIDA GEOLOGICAL SURVEY
Walter Schmidt, State Geologist and Chief

DEPARTMENT OF ENVIRONMENTAL REGULATION
Carol M. Browner, Secretary

DIVISION OF WATER FACILITIES
Richard M. Harvey, Director

BUREAU OF DRINKING WATER AND GROUND WATER RESOURCES
Charles C. Aller, Chief

FLORIDA GEOLOGICAL SURVEY SPECIAL PUBLICATION NO. 34

FLORIDA'S GROUND WATER QUALITY MONITORING PROGRAM

BACKGROUND HYDROGEOCHEMISTRY

EDITED BY

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The most extensive area of nitrate in waters of the Floridan aquifer system in the SRWMD (Figure 46b) is centered on Suwannee County. This is an area known to have contributions of nitrates from agriculture (Upchurch and Lawrence, 1984) and from surface waters recharged through storm-water drainage wells (Hull and Yurewicz, 1979). Lawrence and Upchurch (1982) described the mechanisms of recharge of ammonium and nitrate to the Floridan aquifer system in this area. They found three chemical influences: (1) slowly recharged waters that were affected by contact with the Hawthorn Group, (2) high nitrate waters, which were attributed to rapid infiltration through sinkholes, and (3) ammonium-rich waters that rapidly infiltrated through drainage wells and sinkholes. Other areas of moderate to high nitrate concentrations with similar origins occur in portions of Lafayette, Alachua, Gilchrist, and Dixie Counties. The Floridan is unconfined to poorly confined in all of the areas indicated, and surface runoff drains directly into sinkholes that penetrate the Floridan aquifer system.

Similar arguments can be made for the spotty distribution of nitrate in waters of the Floridan aquifer system in the SJRWMD (Figure 46c). High nitrate concentrations occur under the agricultural areas that extend across the center of the district from St. Johns and Flagler Counties to Marion County. The western and central portions of this belt have high recharge potentials (Scott et al., 1991), but the eastern third does not. The sources of nitrates in the high recharge areas are similar to those of the SRWMD, while the causes of high nitrates in the eastern part of the district are less easily identified. It is possible that recharge is being induced by pumpage in the eastern area.

Nitrates in the SWFWMD (Figure 46d) also reflect differences in recharge potential. The northern half of the district, which is characterized by high recharge potential, has a spotty pattern of nitrate concentrations that reflects local land uses. The Floridan is better confined in the southern half of the district, and nitrate concentrations are characteristically lower.

There is little data for the distribution of nitrate concentrations in the Floridan aquifer system in the SFWMD (Figure 46e). Most values are at or below detection limits.

OTHER CONSTITUENTS

The constituents discussed in this section include the general descriptors of water quality (Total Dissolved Solids and Specific Conductance) and the organic chemistry of the state's aquifer systems. The discussions of organic compounds in the aquifer systems are divided into three subjects: Total Organic Carbon, Synthetic Organics, and Pesticides. Total Organic Carbon is a measure of the natural organic content of the water, while Pesticides and Synthetic Organics reflect anthropogenic compounds.

Total Dissolved Solids

IMPORTANCE

Total dissolved solids (TDS) is a measure of the total mass of ions dissolved in water. The procedure for determining total dissolved solids involves weighing the mass of salts deposited after the water is evaporated. Volatile materials may be lost in this procedure, and there is some difficulty in obtaining a moisture-free environment for weighing. Consequently, total dissolved solids is, at best, a general estimator of the total load of chemicals dissolved in the water.

The more reactive a rock is, the higher the total dissolved solids content of waters within that rock are likely to be. For example, total dissolved solids are likely to be higher in a limestone aquifer than in a siliciclastic aquifer. Total dissolved solids also tends to increase with residence time and as water progresses along a flow path. An important consequence of this is that waters in the Floridan aquifer system that go deep into the aquifer system and contact the reactive, gypsum- and anhydrite-bearing lower confining beds may contain high total dissolved solids due to dissolved calcium and sulfate (Table 4). Therefore, total dissolved solids can be used to understand the chemical maturation and flow history of certain aquifer systems.

Total dissolved solids in the Floridan aquifer system have been discussed by Shampine (1975), Kaufman and Dion (1967, 1968), Hull and Irwin (1979), Sprinkle (1989), and others. Sprinkle (1982b) presents a map of the distribution of total dissolved solids in the Floridan aquifer system. Sprinkle's map agrees in general with the data presented below, although the level of detail of his map is less.

STANDARD OR GUIDANCE CRITERION

The Florida Secondary Drinking Water standard for total dissolved solids is 500 mg/L (F.A.C. CH. 17-550.310-320; Florida Department of Environmental Regulation, 1989). This standard is based on a number of concerns. Waters with high total dissolved solids content have an unpleasant taste. The high total dissolved solids may result in development of scale and precipitates in water, especially in boilers, hot water heaters, and other heated-water systems. Finally, persons who consume high total dissolved solids water are at risk of developing kidney and gall stones.

Table 25 summarizes the samples found to exceed the 500 mg/L standard. Since the Background Network includes wells that are located in the salt-water transition zone, the number of samples found to exceed the standard largely reflects deeper wells, that sample the transition zone near the lower confining beds, and coastal wells. Statewide, 22 percent of samples from the surficial aquifer system exceeded the standard. Most of the samples that exceeded the standard came from the SFWMD (Table 25), where upconing of connate water and coastal intrusion are widespread. Samples from the intermediate aquifer system include 37 percent that exceed the standard. These exceedances are largely located in southwest SWFWMD and western SFWMD, where the Hawthorn Group is extensive and utilized as a water source. The high total dissolved solids waters are located in coastal areas and regions of upconing. Thirty-one percent of the samples from the Floridan aquifer system exceeded the standard. These samples are uniformly distributed through the districts and reflect coastal and upconing areas in the aquifer system. Given the purposeful location of wells in transition zones, little significance can be attached to the high proportion of samples that exceeded the standard. Examination of the maps discussed below is a better way of evaluating the total dissolved solids content of the potable portions of the aquifer systems.

DISTRIBUTION IN GROUND WATER

The distribution of total dissolved solids in Florida ground waters is summarized in Table 25. Note that, while several important trends are apparent, the data reflect all samples from within a district. Some districts utilized monitor wells that are either near the coastal salt-water transition zone or the base of the aquifer system. These wells yield high total dissolved solids waters and bias the summary statistics.

The most significant patterns in total dissolved solids data (Table 25) reflect equilibration with carbonates and poor flushing of aquifer systems. In the surficial aquifer system, total dissolved solids tends to increase southward, which reflects the increase in reactive carbonate minerals in the surficial and intermediate aquifer systems southward. Total dissolved solids data from the Floridan aquifer system show similar medians for all districts except the SFWMD. The high total dissolved solids concentrations in the SFWMD reflect low quality of water in the Floridan over much of the district. This is a result of incomplete flushing of the aquifer system due to low hydraulic heads.

Surficial Aquifer System

Figure 47 illustrates the distribution of total dissolved solids in water of the surficial aquifer system. Total dissolved solids concentrations are quite low, indicating minimum weathering of the siliciclastic host rock materials in NWFWMD and SRWMD. There is an increase in total dissolved solids towards the coast and Escambia Bay within the Sand and Gravel Aquifer (Figure 47a). There are a few coastal wells that exhibit high total dissolved solids in SJRWMD (Figure 47c), but most inland wells have low total dissolved solids waters. The high total dissolved solids coastal wells are in areas of both connate water and heavy pumpage, which may have induced some salt-water intrusion. Coastal salt-water intrusion is well documented in SWFWMD (Figure 47d), where the 250 mg/L total dissolved solids isoline in the surficial aquifer system parallels the coast and major embayments. The high total dissolved solids content of waters in the re-entrant along the Peace River axis result from calcium-sulfate rich waters that are released to the surficial aquifer system by irrigation and natural upwelling.

The reverse is somewhat true in SFWMD (Figure 47e). SFWMD can be divided into three zones (Figure 47e): the Kissimmee and Caloosahatchee watersheds, the Everglades and Big Cypress Swamp, and the Atlantic Coastal Ridge. In the Kissimmee and Caloosahatchee watersheds, the total dissolved solids concentrations range from below 250 mg/L to over 500 mg/L. Highest total dissolved solids waters seem to follow the rivers and most likely represent

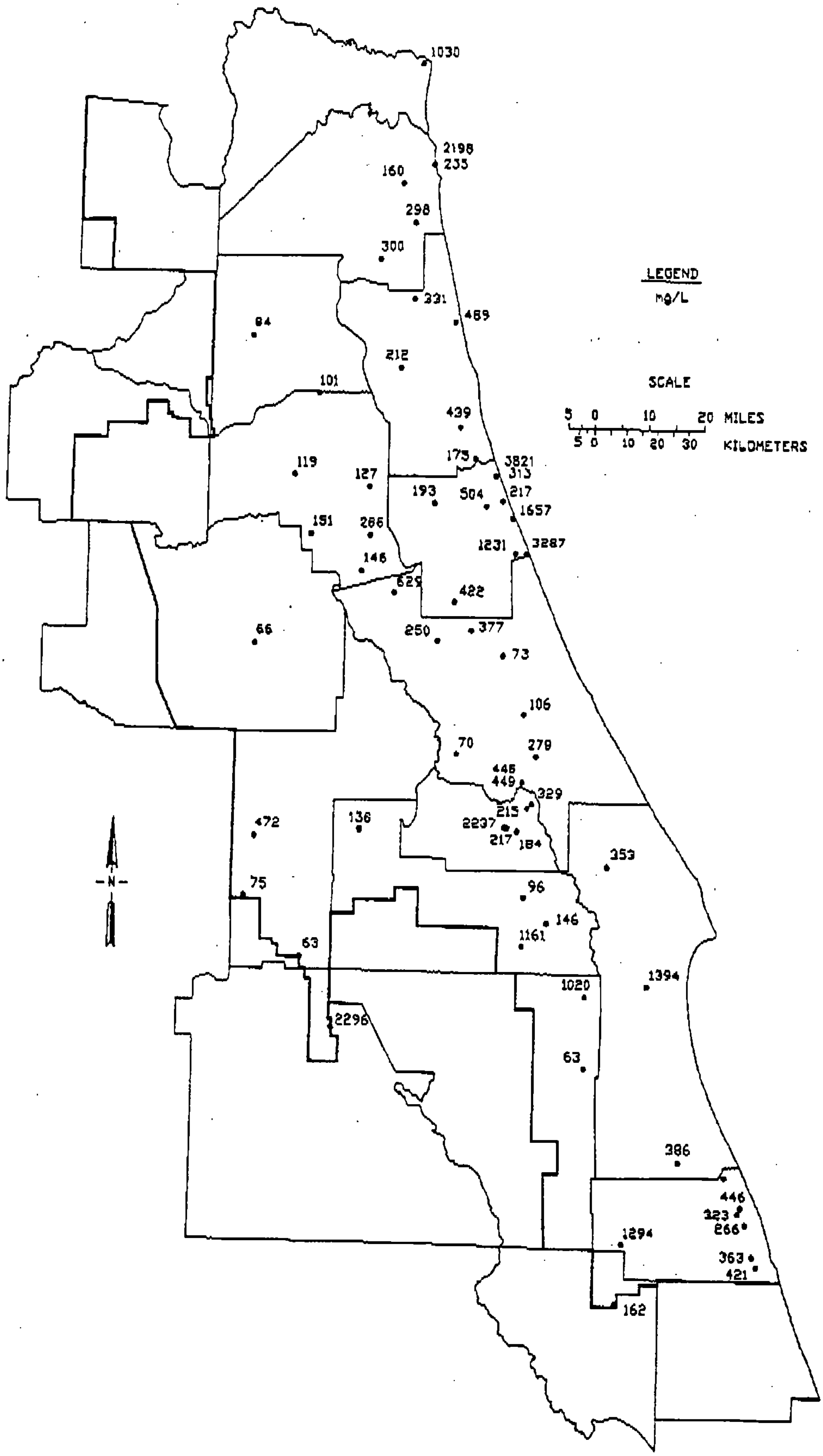
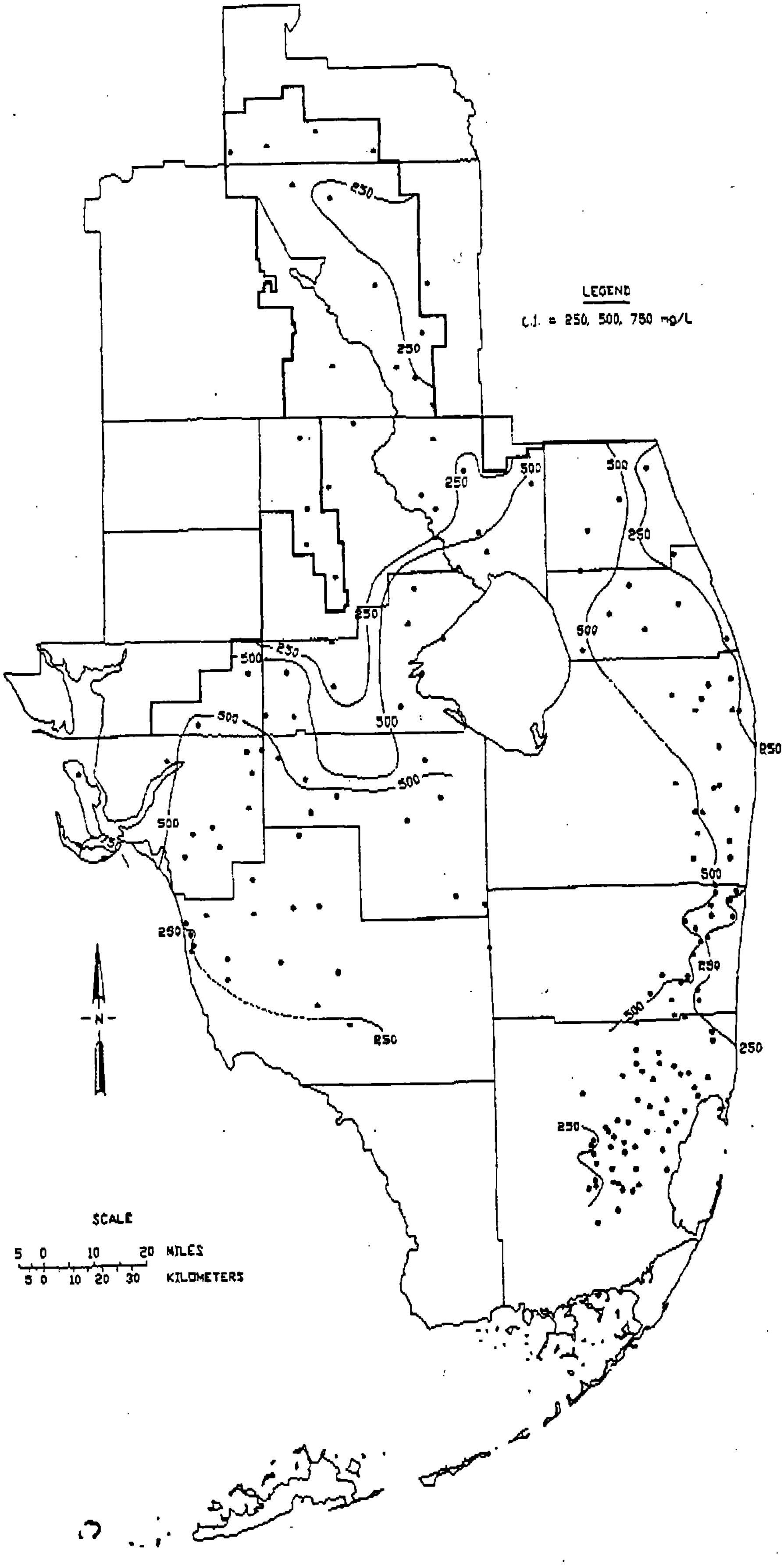


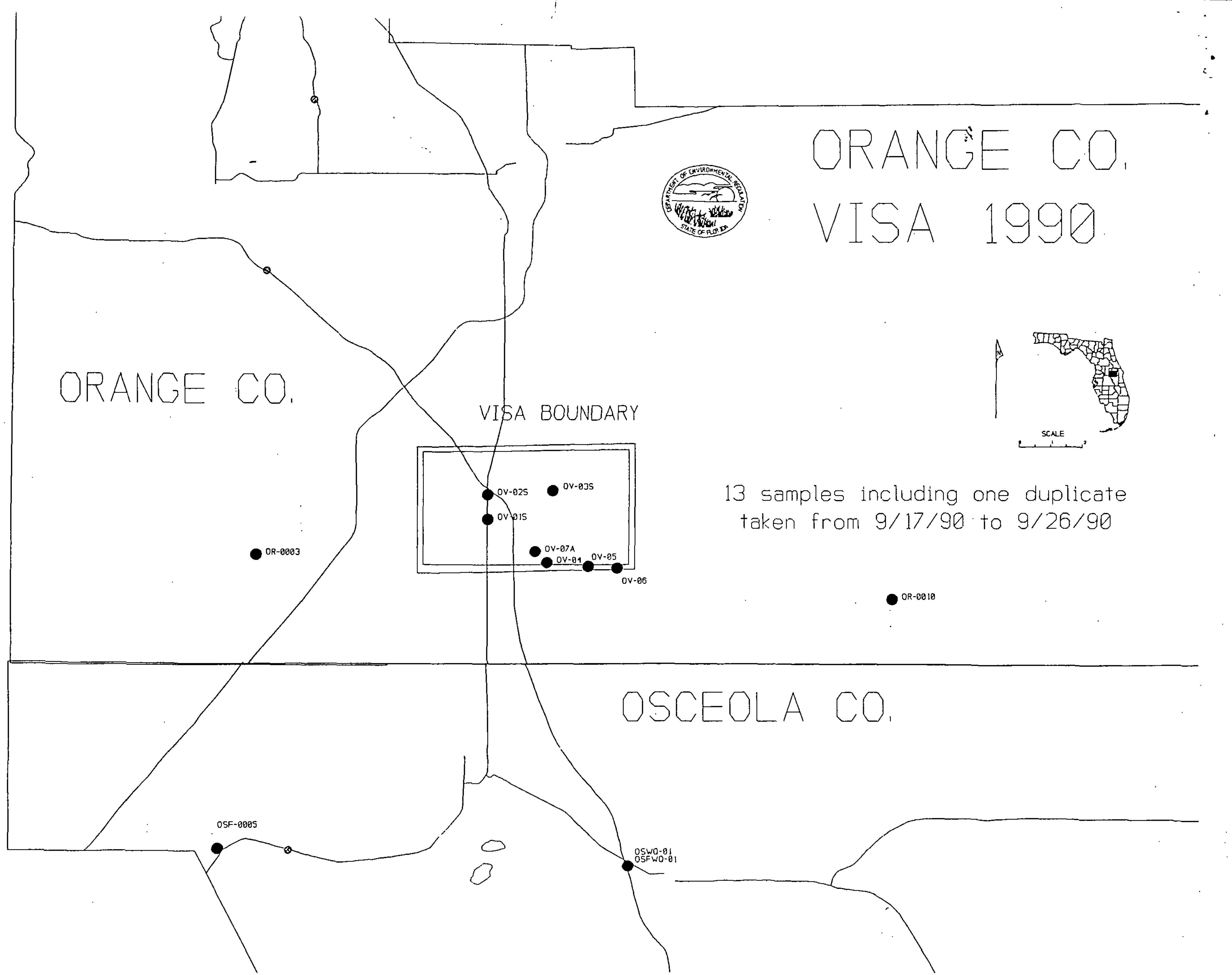
Figure 47c. Distribution of total dissolved solids (TDS; mg/L) in the surficial aquifer system, SJRWMD.


LEGEND
C.I. = 250, 500, 750 mg/L
250
500
N
SCALE
5 0 10 20 MILES
5 0 10 20 30 KILOMETERS

[illegible]

Positive Findings, Orange County VISA, Page 1.

Sample	Sample Date	Parameter, Value
OV-01S	9/18/90	Iron, 0.981 mg/L
OV-02S	9/20/90	Iron, 3.470 mg/L
OV-03S	9/17/90	Iron, 4.620 mg/L
OV-04	9/18/90	Iron, 0.970 mg/L
OV-05	9/18/90	Iron, 1.560 mg/L
OV-06	9/18/90	Iron, 1.130 mg/L
OR-0010	9/18/90	Iron, 0.724 mg/L
OSWQ-01	9/19/90	Iron, 1.250 mg/L Manganese, 0.051 mg/L
OSWQ-02	9/19/90	Iron, 1.290 mg/L Manganese, 0.052 mg/L



ORANGE CO.
VISA 1990
DEPARTMENT OF ENVIRONMENTAL REGULATION
STATE OF FLORIDA
SCALE
ORANGE CO.
VISA BOUNDARY
OV-02S
OV-03S
OV-01S
OV-07A
OV-04
OV-05
OV-06
OR-0003
OR-0010
13 samples including one duplicate
taken from 9/17/90 to 9/26/90
OSCEOLA CO.
OSF-0005
OSWQ-01
OSFWQ-01

(b) Are carcinogenic, mutagenic, teratogenic, or toxic to human beings, unless specific criteria are established for such components in Rule 17-520.420, F.A.C.; or

(c) Are acutely toxic to indigenous species of significance to the aquatic community within surface waters affected by the ground water at the point of contact with surface waters; or

(d) Pose a serious danger to the public health, safety, or welfare; or

(e) Create or constitute a nuisance; or

(f) Impair the reasonable and beneficial use of adjacent waters.

(2) The minimum criteria shall not apply to Class G-IV ground water, unless the Department determines there is a danger to the public health, safety or welfare.

(3) The following procedures shall apply in the implementation of (1)(b) above:

(a) The Secretary is authorized to make determinations, in individual permitting or enforcement proceedings, that a particular level for a substance is a prohibited concentration in violation of a minimum criterion pursuant to (1)(b) above. This determination may not be delegated to Department districts.

(b) Any notice of proposed agency action published pursuant to Rule 17-103.150, F.A.C., which contains such a determination shall include notification of the particular substance and prohibited concentration level being proposed. The notice shall be submitted to the Florida Administrative Weekly at the time it is sent to the permit applicant for publication.

(c) The Department shall notify the Commission semiannually of every application of a determination to a discharger made by the Secretary during the preceding six months pursuant to (a) above for any constituent and concentration level not adopted by the Commission as a rule. The notification shall identify the discharger(s) to whom the application of a determination has been made, the type of industry, the constituent and concentration level set and a summary of the basis for the determination. At the written request of the Commission or any substantially affected member of the public, the Department shall, within 120 days of the written request, submit to the Florida Administrative Weekly a notice of rulemaking pursuant to Section 120.54(1), F.S., on the determination for the particular constituent and concentration level that is the subject of a notification in the preceding sentence.

(d) The application of the determination under paragraph (a) to the permittee or to other affected dischargers shall be subject to:

1. Modification where necessary to conform to any final rulemaking action of the Commission under (c) above; or

2. Withdrawal if the Commission elects not to adopt a corresponding rule after initiation of rulemaking for the constituent under (c) above.

(e) The notice procedures contained in subsection (3) shall not act as a stay of Department enforcement proceedings.

(f) Once a particular standard for a criterion is established by the Commission, it shall be listed in this section.

Specific Authority: 403.061, F.S.
Law Implemented: 403.021, 403.061, F.S.
History: Formerly 17-3.051, Amended and Renumbered 1-1-83, Formerly 17-3.402, Amended 9-8-92.

17-520.410 Classification of Ground Water, Usage, Reclassification.

(1) All ground water of the State is classified according to designated uses as follows:

Class F-I	Potable water use, ground water in a single source aquifer described in Rule 17-520.460, F.A.C. which has a total dissolved solids content of less than 3,000 mg/l and was specifically reclassified as Class F-I by the Commission.
Class G-I	Potable water use, ground water in single source aquifers which has a total dissolved solids content of less than 3,000 mg/l.
Class G-II	Potable water use, ground water in aquifers which has a total dissolved solids content of less than 10,000 mg/l, unless otherwise classified by the Commission.
Class G-III	Non-potable water use, ground water in unconfined aquifers which has a total dissolved solids content of 10,000 mg/l or greater; or which has total dissolved solids of 3,000-10,000 mg/l and either has been reclassified by the Commission as having no reasonable potential as a future source of drinking water, or has been designated by the Department as an exempted aquifer pursuant to Rule 17-28.130(3), F.A.C.

(12) "Pollution" means the presence in the outdoor atmosphere or waters of the state of any substances, contaminants, noise, or man-made or man-induced alteration of the chemical, physical, biological or radiological integrity of air or water in quantities or levels which are or may be potentially harmful or injurious to human health or welfare, animal or plant life, or property, including outdoor recreation.

(13) "Secretary" means the Secretary of the Department.

(14) "Single Source Aquifer" means an aquifer or a portion of an aquifer which, pursuant to Rule 17-520.410(5) and (6), F.A.C., is determined by the Commission to be the only reasonably available source of potable water to a significant segment of the population.

(15) "Site" means the area within an installation's property boundary where effluents are released or applied to the ground water.

(16) "Surface Water" means water upon the surface of the earth, whether contained in bounds created naturally or artificially or diffused. Water from natural springs shall be classified as surface water when it exits from the spring onto the earth's surface.

(17) "Unconfined Aquifer" means an aquifer other than a confined aquifer.

(18) "Waters" include, but are not limited to, rivers, lakes, streams, springs, impoundments, and all other waters or bodies of water, including fresh, brackish, saline, tidal, surface or underground waters. Waters owned entirely by one person other than the state are included only in regard to possible discharge on other property or water. Underground waters include, but are not limited to, all underground waters passing through pores of rock or soils or flowing through in channels, whether manmade or natural.

(19) "Zone of Discharge" means a volume underlying or surrounding the site and extending to the base of a specifically designated aquifer or aquifers, within which an opportunity for the treatment, mixture or dispersion of wastes into receiving ground water is afforded.

(20) "Zone of Saturation" means a subsurface zone in which all of the interstices are filled with water.

Specific Authority: 403.061, F.S.
Law Implemented: 403.021, 403.031, 403.061, F.S.
History: New 9-8-92.

17-520.300 General Provisions for Ground Water Classes, Standards, and Exemptions.

(1) This Chapter contains criteria which are applicable to ground water.

17-520.200(12) - 17-520.300(1)

(2) To determine if the ground water criteria in this Chapter are being met, ground water quality shall be monitored in accordance with this rule and Chapter 17-522, F.A.C.

(3) A violation of any ground water criterion contained in this Chapter constitutes pollution.

(4) In addition to any technology-based effluent limitations required by Department rule, the Department shall also specify water quality-based effluent limitations when necessary to assure that the water quality criteria will be met.

(5) Notwithstanding the classification and criteria for ground water set forth in this Chapter, discharge to ground water shall not impair the designated use of contiguous surface waters.

(6) Compliance with ground water standards shall be determined by analyses of unfiltered ground water samples, unless a filtered sample is as or more representative of the particular ground water quality.

(7) For owners of installations having filed a complete application for a Chapter 403, F.S., permit covering water discharges as of January 1, 1983, or discharging pollutants to ground water as of July 1, 1982, compliance with the minimum criteria set forth in Rule 17-520.400, F.A.C., shall be determined by analysis of the constituents of the waste stream of the installation causing the discharge; provided, however, that the installation owner may, at his option, place a monitoring well immediately outside the site boundary to measure compliance with the minimum criteria, as long as the discharge poses no danger to the public health, safety or welfare.

Specific Authority: 403.061, 403.087, F.S.
Law Implemented: 403.021, 403.061, 403.087, 403.088, 403.502, 403.702, F.S.
History: Formerly 17-3.071, Amended and Renumbered 1-1-83, Formerly 17-3.401, Amended 9-8-92.

17-520.400 Minimum Criteria for Ground Water.

(1) All ground water shall at all places and at all times be free from domestic, industrial, agricultural, or other man-induced non-thermal components of discharges in concentrations which, alone or in combination with other substances, or components of discharges (whether thermal or non-thermal):

(a) Are harmful to plants, animals, or organisms that are native to the soil and responsible for treatment or stabilization of the discharge relied upon by Department permits; or

17-520.300(2) - 17-520.400(1)(a)

46 870624	CHLORIDE,TOTAL			38.0000	mg/l	
46 880628	CHLORIDE,TOTAL			40.0000	mg/l	
46 891016	CHLORIDE,TOTAL			45.2000	mg/l	
46 900119	CHLORIDE,TOTAL			45.2000	mg/l	
46 900412	CHLORIDE,TOTAL			46.1000	mg/l	
46 900710	CHLORIDE,TOTAL			48.8000	mg/l	
46 901017	CHLORIDE,TOTAL			46.2000	mg/l	
328 850710	TOTAL DISSOLVED SOLIDS			56.9000	mg/l	
328 860624	TOTAL DISSOLVED SOLIDS			178.0000	mg/l	
328 870624	TOTAL DISSOLVED SOLIDS			119.9000	mg/l	
328 880628	TOTAL DISSOLVED SOLIDS			175.9000	mg/l	
328 890124	TOTAL DISSOLVED SOLIDS			150.0000	mg/l	
328 891016	TOTAL DISSOLVED SOLIDS			159.0000	mg/l	
328 900119	TOTAL DISSOLVED SOLIDS			170.0000	mg/l	
328 900412	TOTAL DISSOLVED SOLIDS			139.9000	mg/l	
328 901017	TOTAL DISSOLVED SOLIDS			123.1000	mg/l	
-- 282456081241601	282456	812416	28	18	SF OV-01S	
40 900925	SULFATE,DISSOLVED			24.0000	mg/l	PROV
44 900925	CHLORIDE,DISSOLVED IN WATER			21.0000	mg/l	PROV
328 900925	TOTAL DISSOLVED SOLIDS			94.0000	mg/l	PROV
-- 282537081241701	282537	812417	28	18	SF OV-02S	
40 900920	SULFATE,DISSOLVED			1.3000	mg/l	PROV
44 900920	CHLORIDE,DISSOLVED IN WATER			69.0000	mg/l	PROV
328 900920	TOTAL DISSOLVED SOLIDS			225.0000	mg/l	PROV
-- 282544081221301	282544	812213	15	14	SF OV-03S	
40 900925	SULFATE,DISSOLVED			7.1000	mg/l	PROV
44 900925	CHLORIDE,DISSOLVED IN WATER			34.0000	mg/l	PROV
328 900925	TOTAL DISSOLVED SOLIDS			114.0000	mg/l	PROV
-- 282342081222301	282342	812223	15	5	SF OV-04	
40 900925	SULFATE,DISSOLVED			14.0000	mg/l	PROV
44 900925	CHLORIDE,DISSOLVED IN WATER			5.1000	mg/l	PROV
328 900925	TOTAL DISSOLVED SOLIDS			66.0000	mg/l	PROV
-- 282336081210401	282336	812104	16	6	SF OV-05	
40 900925	SULFATE,DISSOLVED			6.2000	mg/l	PROV
44 900925	CHLORIDE,DISSOLVED IN WATER			12.0000	mg/l	PROV
328 900925	TOTAL DISSOLVED SOLIDS			54.0000	mg/l	PROV
-- 282333081200901	282333	812009	16	6	SF OV-06	
40 900925	SULFATE,DISSOLVED			9.5000	mg/l	PROV
44 900925	CHLORIDE,DISSOLVED IN WATER			4.1000	mg/l	PROV
328 900925	TOTAL DISSOLVED SOLIDS			52.0000	mg/l	PROV
-- 282401081224501	282401	812245	19	9	SF OV-07A	
40 900919	SULFATE,DISSOLVED			32.0000	mg/l	PROV
40 900925	SULFATE,DISSOLVED			6.8000	mg/l	PROV
44 900919	CHLORIDE,DISSOLVED IN WATER			7.7000	mg/l	PROV
44 900925	CHLORIDE,DISSOLVED IN WATER			7.0000	mg/l	PROV
328 900919	TOTAL DISSOLVED SOLIDS			71.0000	mg/l	PROV
328 900925	TOTAL DISSOLVED SOLIDS			46.0000	mg/l	PROV

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***********************************************
** DATA MARKED "PROV" IS PROVISIONAL DATA
** AND IS SUBJECT TO CHANGE -- DO NOT RELEASE
** OR USE FOR OFFICIAL WORK!
***********************************************
-- 282608081221601     282608    812216    7      7      SF MR-0004
 42 850710  SULFATE,TOTAL                         4.0000  mg/l
 42 860624  SULFATE,TOTAL                        10.7000  mg/l
 46 850710  CHLORIDE,TOTAL                        1.9000  mg/l
 46 860624  CHLORIDE,TOTAL                        8.2000  mg/l
328 850710  TOTAL DISSOLVED SOLIDS               90.0000  mg/l
328 860624  TOTAL DISSOLVED SOLIDS               73.1000  mg/l
-- 282353081313701     282353    813137    18     18     SF OR-0003
 42 850710  SULFATE,TOTAL                        54.3000  mg/l
 42 860624  SULFATE,TOTAL                        38.5000  mg/l
 42 870623  SULFATE,TOTAL                        26.1000  mg/l
 42 880908  SULFATE,TOTAL                        23.0000  mg/l
 42 890321  SULFATE,TOTAL                        25.6000  mg/l
 42 890612  SULFATE,TOTAL                        28.7000  mg/l
 42 890807  SULFATE,TOTAL                        23.5000  mg/l
 42 891016  SULFATE,TOTAL                        34.4000  mg/l
 42 900119  SULFATE,TOTAL                        46.6000  mg/l
 42 900412  SULFATE,TOTAL                        29.8000  mg/l
 42 900710  SULFATE,TOTAL                        37.1000  mg/l
 46 850710  CHLORIDE,TOTAL                       29.2000  mg/l
 46 860624  CHLORIDE,TOTAL                       20.1000  mg/l
 46 870623  CHLORIDE,TOTAL                       30.0000  mg/l
 46 880908  CHLORIDE,TOTAL                       29.0000  mg/l
 46 890321  CHLORIDE,TOTAL                       36.6000  mg/l
 46 890612  CHLORIDE,TOTAL                       30.8000  mg/l
 46 890807  CHLORIDE,TOTAL                       42.8000  mg/l
 46 891016  CHLORIDE,TOTAL                       36.7000  mg/l
 46 900119  CHLORIDE,TOTAL                       37.7000  mg/l
 46 900412  CHLORIDE,TOTAL                       58.9000  mg/l
 46 900710  CHLORIDE,TOTAL                       69.8000  mg/l
328 850710  TOTAL DISSOLVED SOLIDS              299.0000  mg/l
328 860624  TOTAL DISSOLVED SOLIDS              176.1000  mg/l
328 870623  TOTAL DISSOLVED SOLIDS              157.9000  mg/l
328 880908  TOTAL DISSOLVED SOLIDS              159.0000  mg/l
328 890321  TOTAL DISSOLVED SOLIDS              177.9000  mg/l
328 890612  TOTAL DISSOLVED SOLIDS              193.9000  mg/l
328 890807  TOTAL DISSOLVED SOLIDS              211.9000  mg/l
328 891016  TOTAL DISSOLVED SOLIDS              222.0000  mg/l
328 900119  TOTAL DISSOLVED SOLIDS              219.1000  mg/l
328 900412  TOTAL DISSOLVED SOLIDS              242.9000  mg/l
328 900710  TOTAL DISSOLVED SOLIDS              309.9000  mg/l
 40 900920  SULFATE,DISSOLVED                    71.0000  mg/l      PROV
 44 900920  CHLORIDE,DISSOLVED IN WATER          69.0000  mg/l      PROV
328 900920  TOTAL DISSOLVED SOLIDS              382.0000  mg/l      PROV
-- 282257081383201     282257    813832    83     0      SF OR-0004
 42 850710  SULFATE,TOTAL                         3.7000  mg/l
 42 860624  SULFATE,TOTAL                         3.3000  mg/l
 42 870623  SULFATE,TOTAL                  <      5.0000  mg/l
 46 850710  CHLORIDE,TOTAL                        2.8000  mg/l
 46 860624  CHLORIDE,TOTAL                        5.5000  mg/l
 46 870623  CHLORIDE,TOTAL                        6.7000  mg/l
328 850710  TOTAL DISSOLVED SOLIDS              161.0000  mg/l
328 860624  TOTAL DISSOLVED SOLIDS              166.0000  mg/l
328 870623  TOTAL DISSOLVED SOLIDS              161.0000  mg/l
328 890124  TOTAL DISSOLVED SOLIDS              123.9000  mg/l
-- 282241081112802     282241    811128    29     26     SF OR-0010
 42 850710  SULFATE,TOTAL                         6.8000  mg/l
 42 860624  SULFATE,TOTAL                         8.2000  mg/l
 42 870624  SULFATE,TOTAL                  <      5.0000  mg/l
 42 880628  SULFATE,TOTAL                  <      2.0000  mg/l
 42 891016  SULFATE,TOTAL                  <      2.0000  mg/l
 42 900119  SULFATE,TOTAL                  <      2.0000  mg/l
 42 900412  SULFATE,TOTAL                  <      2.0000  mg/l
 42 900710  SULFATE,TOTAL                  <      2.0000  mg/l
 42 901017  SULFATE,TOTAL                  <      2.0000  mg/l
 46 850710  CHLORIDE,TOTAL                       35.3000  mg/l
 46 860624  CHLORIDE,TOTAL                       36.5000  mg/l
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STATE OF FLORIDA

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FLORIDA GEOLOGICAL SURVEY SPECIAL PUBLICATION NO. 34

FLORIDA'S GROUND WATER QUALITY MONITORING PROGRAM

BACKGROUND HYDROGEOCHEMISTRY

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The most extensive area of nitrate in waters of the Floridan aquifer system in the SRWMD (Figure 46b) is centered on Suwannee County. This is an area known to have contributions of nitrates from agriculture (Upchurch and Lawrence, 1984) and from surface waters recharged through storm-water drainage wells (Hull and Yurewicz, 1979). Lawrence and Upchurch (1982) described the mechanisms of recharge of ammonium and nitrate to the Floridan aquifer system in this area. They found three chemical influences: (1) slowly recharged waters that were affected by contact with the Hawthorn Group, (2) high nitrate waters, which were attributed to rapid infiltration through sinkholes, and (3) ammonium-rich waters that rapidly infiltrated through drainage wells and sinkholes. Other areas of moderate to high nitrate concentrations with similar origins occur in portions of Lafayette, Alachua, Gilchrist, and Dixie Counties. The Floridan is unconfined to poorly confined in all of the areas indicated, and surface runoff drains directly into sinkholes that penetrate the Floridan aquifer system.

Similar arguments can be made for the spotty distribution of nitrate in waters of the Floridan aquifer system in the SJRWMD (Figure 46c). High nitrate concentrations occur under the agricultural areas that extend across the center of the district from St. Johns and Flagler Counties to Marion County. The western and central portions of this belt have high recharge potentials (Scott et al., 1991), but the eastern third does not. The sources of nitrates in the high recharge areas are similar to those of the SRWMD, while the causes of high nitrates in the eastern part of the district are less easily identified. It is possible that recharge is being induced by pumpage in the eastern area.

Nitrates in the SWFWMD (Figure 46d) also reflect differences in recharge potential. The northern half of the district, which is characterized by high recharge potential, has a spotty pattern of nitrate concentrations that reflects local land uses. The Floridan is better confined in the southern half of the district, and nitrate concentrations are characteristically lower.

There is little data for the distribution of nitrate concentrations in the Floridan aquifer system in the SFWMD (Figure 46e). Most values are at or below detection limits.

OTHER CONSTITUENTS

The constituents discussed in this section include the general descriptors of water quality (Total Dissolved Solids and Specific Conductance) and the organic chemistry of the state's aquifer systems. The discussions of organic compounds in the aquifer systems are divided into three subjects: Total Organic Carbon, Synthetic Organics, and Pesticides. Total Organic Carbon is a measure of the natural organic content of the water, while Pesticides and Synthetic Organics reflect anthropogenic compounds.

Total Dissolved Solids

IMPORTANCE

Total dissolved solids (TDS) is a measure of the total mass of ions dissolved in water. The procedure for determining total dissolved solids involves weighing the mass of salts deposited after the water is evaporated. Volatile materials may be lost in this procedure, and there is some difficulty in obtaining a moisture-free environment for weighing. Consequently, total dissolved solids is, at best, a general estimator of the total load of chemicals dissolved in the water.

The more reactive a rock is, the higher the total dissolved solids content of waters within that rock are likely to be. For example, total dissolved solids are likely to be higher in a limestone aquifer than in a siliciclastic aquifer. Total dissolved solids also tends to increase with residence time and as water progresses along a flow path. An important consequence of this is that waters in the Floridan aquifer system that go deep into the aquifer system and contact the reactive, gypsum- and anhydrite-bearing lower confining beds may contain high total dissolved solids due to dissolved calcium and sulfate (Table 4). Therefore, total dissolved solids can be used to understand the chemical maturation and flow history of certain aquifer systems.

Total dissolved solids in the Floridan aquifer system have been discussed by Shampine (1975), Kaufman and Dion (1967, 1968), Hull and Irwin (1979), Sprinkle (1989), and others. Sprinkle (1982b) presents a map of the distribution of total dissolved solids in the Floridan aquifer system. Sprinkle's map agrees in general with the data presented below, although the level of detail of his map is less.

STANDARD OR GUIDANCE CRITERION

The Florida Secondary Drinking Water standard for total dissolved solids is 500 mg/L (F.A.C. CH. 17-550.310-320; Florida Department of Environmental Regulation, 1989). This standard is based on a number of concerns. Waters with high total dissolved solids content have an unpleasant taste. The high total dissolved solids may result in development of scale and precipitates in water, especially in boilers, hot water heaters, and other heated-water systems. Finally, persons who consume high total dissolved solids water are at risk of developing kidney and gall stones.

Table 25 summarizes the samples found to exceed the 500 mg/L standard. Since the Background Network includes wells that are located in the salt-water transition zone, the number of samples found to exceed the standard largely reflects deeper wells, that sample the transition zone near the lower confining beds, and coastal wells. Statewide, 22 percent of samples from the surficial aquifer system exceeded the standard. Most of the samples that exceeded the standard came from the SFWMD (Table 25), where upconing of connate water and coastal intrusion are widespread. Samples from the intermediate aquifer system include 37 percent that exceed the standard. These exceedances are largely located in southwest SWFWMD and western SFWMD, where the Hawthorn Group is extensive and utilized as a water source. The high total dissolved solids waters are located in coastal areas and regions of upconing. Thirty-one percent of the samples from the Floridan aquifer system exceeded the standard. These samples are uniformly distributed through the districts and reflect coastal and upconing areas in the aquifer system. Given the purposeful location of wells in transition zones, little significance can be attached to the high proportion of samples that exceeded the standard. Examination of the maps discussed below is a better way of evaluating the total dissolved solids content of the potable portions of the aquifer systems.

DISTRIBUTION IN GROUND WATER

The distribution of total dissolved solids in Florida ground waters is summarized in Table 25. Note that, while several important trends are apparent, the data reflect all samples from within a district. Some districts utilized monitor wells that are either near the coastal salt-water transition zone or the base of the aquifer system. These wells yield high total dissolved solids waters and bias the summary statistics.

The most significant patterns in total dissolved solids data (Table 25) reflect equilibration with carbonates and poor flushing of aquifer systems. In the surficial aquifer system, total dissolved solids tends to increase southward, which reflects the increase in reactive carbonate minerals in the surficial and intermediate aquifer systems southward. Total dissolved solids data from the Floridan aquifer system show similar medians for all districts except the SFWMD. The high total dissolved solids concentrations in the SFWMD reflect low quality of water in the Floridan over much of the district. This is a result of incomplete flushing of the aquifer system due to low hydraulic heads.

Surficial Aquifer System

Figure 47 illustrates the distribution of total dissolved solids in water of the surficial aquifer system. Total dissolved solids concentrations are quite low, indicating minimum weathering of the siliciclastic host rock materials in NWFWMD and SRWMD. There is an increase in total dissolved solids towards the coast and Escambia Bay within the Sand and Gravel Aquifer (Figure 47a). There are a few coastal wells that exhibit high total dissolved solids in SJRWMD (Figure 47c), but most inland wells have low total dissolved solids waters. The high total dissolved solids coastal wells are in areas of both connate water and heavy pumpage, which may have induced some salt-water intrusion. Coastal salt-water intrusion is well documented in SWFWMD (Figure 47d), where the 250 mg/L total dissolved solids isoline in the surficial aquifer system parallels the coast and major embayments. The high total dissolved solids content of waters in the re-entrant along the Peace River axis result from calcium-sulfate rich waters that are released to the surficial aquifer system by irrigation and natural upwelling.

The reverse is somewhat true in SFWMD (Figure 47e). SFWMD can be divided into three zones (Figure 47e): the Kissimmee and Caloosahatchee watersheds, the Everglades and Big Cypress Swamp, and the Atlantic Coastal Ridge. In the Kissimmee and Caloosahatchee watersheds, the total dissolved solids concentrations range from below 250 mg/L to over 500 mg/L. Highest total dissolved solids waters seem to follow the rivers and most likely represent

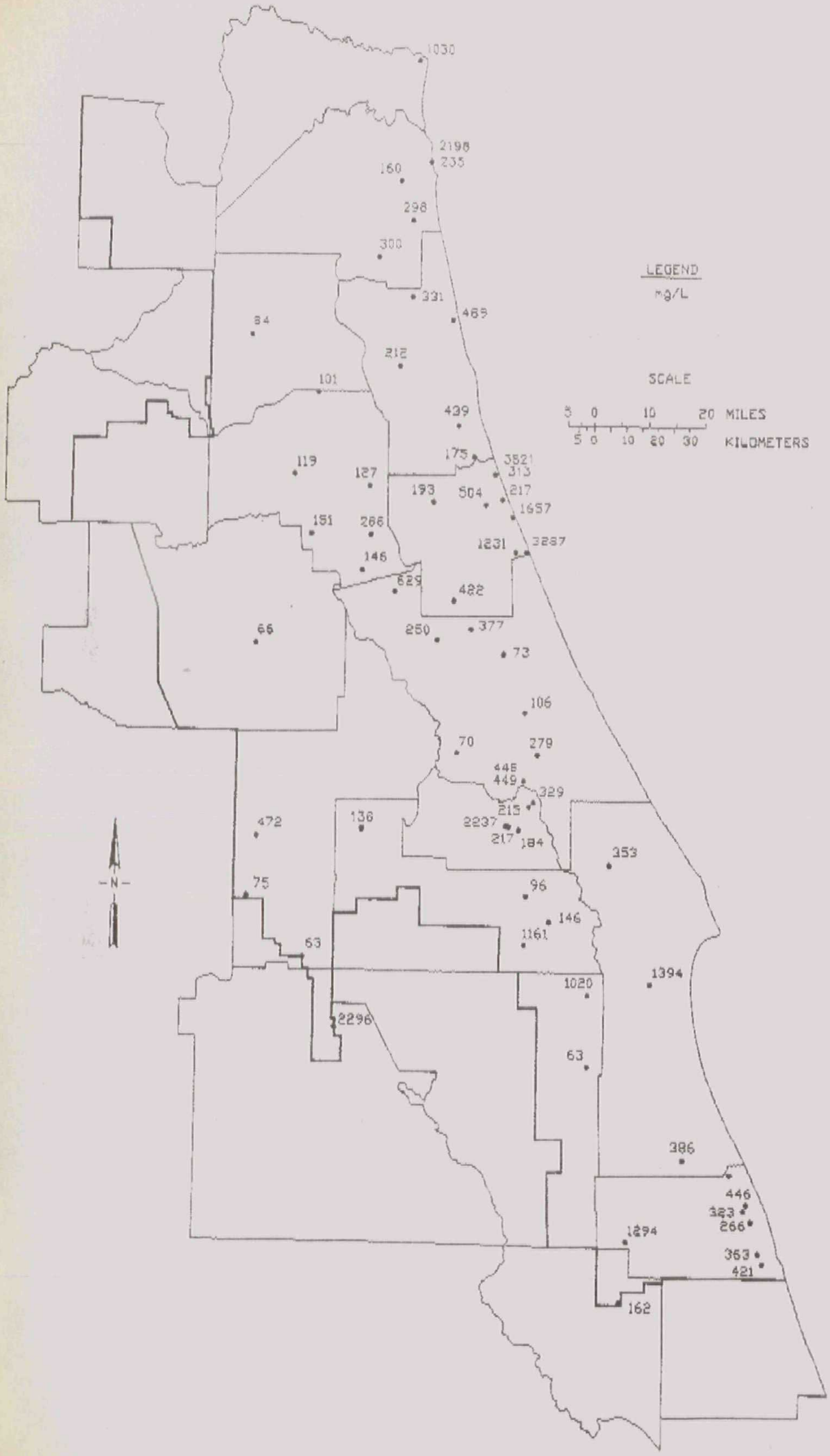

Figure 47c. Distribution of total dissolved solids (TDS; mg/L) in the surficial aquifer system, SJRWMD.

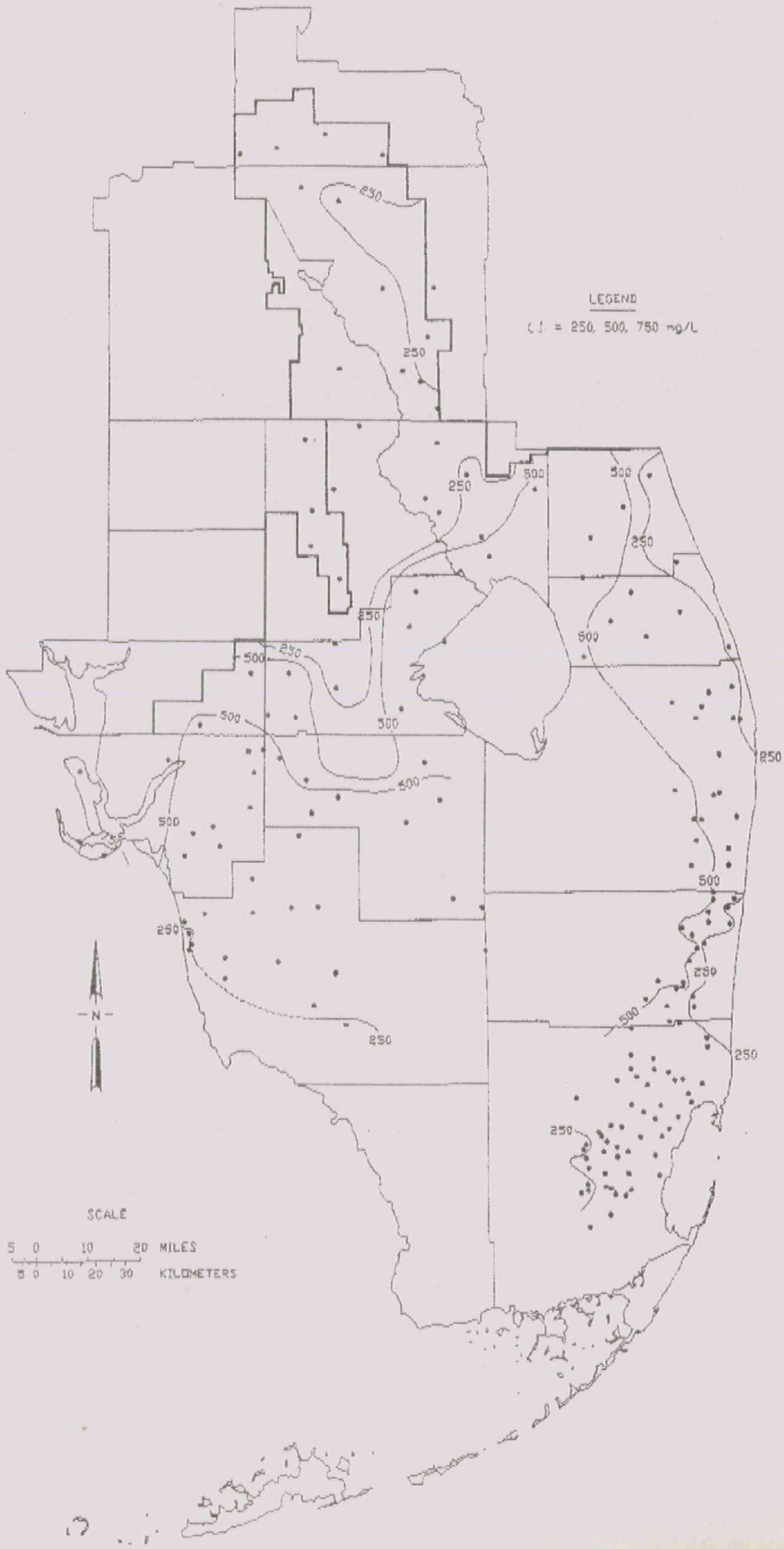

Figure [illegible]. Distribution of total dissolved solids (TDS, mg/L) in the surficial aquifer

REFERENCE 26

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV

345 COURTLAND STREET, N.E.
ATLANTA, GEORGIA 30365

4WD-WPB

Ms. Anne Bradner
United States Department of the Interior
Geological Survey
Water Resources Division
224 West Center Street
Suite 1006
Altamonte Springs, Florida 32714

Dear Ms. Bradner:

The Environmental Protection Agency (EPA) is currently assessing the Chevron Chemical site located at 3100 Orange Blossom Trail in Orlando, Florida. In order to identify a threat to the ground water, we are attempting to document an aquifer interconnection between the surficial and Floridan aquifers.

As we discussed in our telephone conversation on April 28, 1993, your research of drainage wells in Orlando, Florida, would document the aquifer interconnection in the site area. Enclosed is a map of the area of which I have interest. Please identify the well locations, their depths, and whether the wells have been capped on this map within a 2-mile radius of the site. Include the latitude and longitude for each well if available. I would also appreciate any additional information for the Orlando area and the Emerald Springs Sinkhole.

Thank you for your cooperation in this matter. If you have any questions, please contact me or Dorothy Rayfield at (404) 347-5065.

Sincerely,

Cynthia K. Gurley 4/27/93

Cynthia K. Gurley
Site Assessment Manager
South Unit

Enclosure

United States Department of the Interior

TAKE PRIDE IN AMERICA

GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
224 West Central Parkway
Suite 1006
Altamonte Springs, Florida 32714

May 17, 1993

Cynthia Gurley
Site Assessment Manager
U.S. Environmental Protection Agency
Region 4
345 Courtland Street, N.E.
Atlanta, GA 30365

Dear Ms. Gurley:

I received your request for information on wells in the vicinity of the Chevron Chemical site on Orange Blossom Trail in Orlando, Florida. We have work maps of the plotted locations of all drainage wells on the Orlando East and Orlando West topo quads. The wells are plotted with a legend as to type of drainage well, and have total depth and casing depth plotted beside each site (if known).

I am also enclosing a list of all wells within the 4-mile vicinity of the site. The station number is a combination of latitude, longitude, and sequence number (used if there is more than one well in one second of grid). Use of most wells on this list are W (withdrawal), D (drainage), O (observations), or Z (destroyed). Aquifer codes include 120FLRD for Floridan aquifer, 120HTRN for Hawthorn formation which is shallower, and 112NRSD for nonartesian sand or surficial aquifer.

Data for your other request on Emerald Sink is hard to find. At one time, we had a short sketch of the site for a tour of Orlando geologic sites, but no one seems to have a copy anymore. All I could tell you is the site is an open sinkhole about 200-300 feet deep and has a very small surface drainage basin.

If you need more information than these enclosures, please call me at 407-648-6191.

Sincerely,

Anne Bradner

Anne Bradner
Hydrologist

REC'D.
MAY 20 1993
WPB-SAS

#212

DATE: 05/17/93

EPA WELL REQUEST

SITE-ID	PRIMARY USE OF SITE	DEPTH OF WELL (FEET)	DIAMETER OF CASING (IN)	AQUIFER CODE	OWNER
283101081235501	D	--	12.0	120FLRD	ORANGE COUNTY
283101081235601	D	--	8.00	120FLRD	ORANGE COUNTY
283102081223401	W	1280	28.0	120FLRD	ORLANDO UTILITY
283102081231901	D	--	8.00	120FLRD	ORANGE COUNTY
283102081234701	D	--	8.00	120FLRD	ORANGE COUNTY
283102081242201	-	400	--	--	--
283103081221101	W	1210	36.0	120FLRD	ORLANDO UTILITI
283103081231701	D	500	20.0	120FLRD	FLA DEPT TRANS
			--	122HTRNS	--
283105081222201	D	483	12.0	120FLRD	CITY OF ORLANDO
283105081232101	D	450	20.0	120FLRD	FLORIDA DOT
283107081253601	D	460	8.00	120FLRD	ORANGE COUNTY
283107081285601	W	293	3.00	120FLRD	K M DENMAN
283110081275301	W	450	5.00	120FLRD	VALENCIA COLLEG
283111081221101	D	--	--	120FLRD	CITY OF ORLANDO
283111081224201	W	1330	30.0	120FLRD	ORLANDO UTILTY
283112081202601	D	--	12.0	120FLRD	ORANGE COUNTY
283112081213401	-	1330	--	--	ORLANDO UTILITIES
283112081213801	D	706	16.0	120FLRD	CITY OF ORLANDO
283112081214201	D	524	10.0	120FLRD	CITY OF ORLANDO
283113081225601	D	623	12.0	120FLRD	CITY OF ORLANDO
283116081204501	D	350	8.00	120FLRD	H S SYMONDS
283116081212301	D	400	12.0	120FLRD	ORANGE COUNTY
283116081231001	D	202	6.00	120FLRD	CITY OF ORLANDO
283116081252901	W	195	3.00	120FLRD	EARL BROOKLAND
283118081210801	D	435	12.0	120FLRD	ORANGE COUNTY
283118081222801	D	435	12.0	120FLRD	CITY OF ORLANDO
283120081234201	D	--	8.00	120FLRD	ORANGE COUNTY
283121081202901	U	260	6.00	120FLRD	CENT FLA UTIL
			--	--	ORANGE COUNTY
283121081202902	U	265	6.00	120FLRD	CENT FLA UTIL
283121081205101	W	270	4	120FLRD	GRACE CHURCH
283122081225001	W	227	6.00	120FLRD	HOLIDAY HOSPTAL
			--	122HTRNS	--
283125081230101	D	228	12.0	120FLRD	CITY OF ORLANDO
283126081231901	D	452	20.0	120FLRD	CITY OF ORLANDO
283127081203001	D	--	18.0	120FLRD	CITY OF ORLANDO
283127081203002	D	--	8.00	120FLRD	CITY OF ORLANDO
283127081225001	D	451	12.0	120FLRD	CITY OF ORLANDO
283127081233601	D	--	6.00	120FLRD	CITY OF ORLANDO

DATE: 05/17/93 EPA WELL REQUEST

SITE-ID	PRIMARY USE OF SITE	DEPTH OF WELL (FEET)	DIAMETER OF CASING (IN)	AQUIFER CODE	OWNER
283129081222801	D	444	20.0	120FLRD	CITY OF ORLANDO
283130081215501	D	183	12.0	120FLRD	CITY OF ORLANDO
283135081232001	D	513	10.0	120FLRD	CITY OF ORLANDO
283135081234301	W	1230	10.0	120FLRD	LAYNE-ATLANTIC
283140081215701	D	--	12.0	120FLRD	CITY OF ORLANDO
283140081234301	D	460	12.0	120FLRD	CITY OF ORLANDO
283142081225901	D	484	12.0	120FLRD	CITY OF ORLANDO
283143081223001	D	316	10.0	120FLRD	CITY OF ORLANDO
283144081220101	D	416	12.0	120FLRD	CITY OF ORLANDO
283144081224901	D	600	20.0	120FLRD	CITY OF ORLANDO
283144081225001	D	--	--	120FLRD	CITY OF ORLANDO
283144081254201	D	400	16.0	120FLRD	ORANGE COUNTY
283145081220101	Z	416	8.00	120FLRD	CITY OF ORLANDO
283145081220301	D	811	12.0	120FLRD	CITY OF ORLANDO
283145081223301	D	397	12.0	120FLRD	CITY OF ORLANDO
283145081250601	W	208	4.00	120FLRD	DR SCHANCK
			--	122HTRNN	--
283146081223001	D	730	18.0	120FLRD	CITY OF ORLANDO
283146081224901	D	353	10.0	120FLRD	CITY OF ORLANDO
283147081203601	D	464	20.0	120FLRD	CITY OF ORLANDO
283147081214701	D	428	12.0	120FLRD	CITY OF ORLANDO
283147081224301	D	607	20.0	120FLRD	CITY OF ORLANDO
283148081254601	U	253	12.0	120FLRD	ORANGE COUNTY
283150081221601	D	460	12.0	120FLRD	CITY OF ORLANDO
283150081232001	D	300	12.0	120FLRD	CITY OF ORLANDO
283151081235801	D	--	10.0	120FLRD	CITY OF ORLANDO
283152081230201	U	119	3.00	120FLRD	COCA COLA CO
283152081235801	D	--	10.0	120FLRD	CITY OF ORLANDO
283153081200801	D	466	20.0	120FLRD	CITY OF ORLANDO
283153081221501	D	345	10.0	120FLRD	CITY OF ORLANDO
283154081220701	D	668	12.0	120FLRD	ORLANDO
283155081221401	D	350	12.0	120FLRD	CITY OF ORLANDO
283155081231301	D	507	12.0	120FLRD	CITY OF ORLANDO
283155081231302	D	437	6.00	120FLRD	CITY OF ORLANDO
283155081240701	W	93.0	4.00	122HTRNN	DR HANSON
283157081215801	D	335	12.0	120FLRD	CITY OF ORLANDO
283157081233501	D	411	8.00	120FLRD	CITY OF ORLANDO
283157081250601	D	141	8.00	120FLRD	ORANGE COUNTY
283158081220201	D	342	12.0	120FLRD	CITY OF ORLANDO
283201081213401	D	863	12.0	120FLRD	CITY OF ORLANDO

DATE: 05/17/93

EPA WELL REQUEST

SITE-ID	PRIMARY USE OF SITE	DEPTH OF WELL (FEET)	DIAMETER OF CASING (IN)	AQUIFER CODE	OWNER
283201081213402	D	230	12.0	120FLRD	CITY OF ORLANDO
283201081213801	D	139	12.0	120FLRD	CITY OF ORLANDO
283201081213802	D	140	12.0	120FLRD	CITY OF ORLANDO
283201081213803	D	605	12.0	120FLRD	CITY OF ORLANDO
283202081283001	W	--	6.00	120FLRD	B & H SALES
283203081215901	D	392	12.0	120FLRD	CITY OF ORLANDO
283204081223201	D	508	20.0	120FLRD	CITY OF ORLANDO
283204081230701	D	447	12.0	120FLRD	CITY OF ORLANDO
283205081250001	-	1270	--	--	GENERAL WATERWORKS
283207081202901	U	--	14.0	120FLRD	ORLANDO UTIL
283207081234101	D	377	12.0	120FLRD	CITY OF ORLANDO
283207081234301	D	444	20.0	120FLRD	CITY OF ORLANDO
283207081234601	D	448	20.0	120FLRD	CITY OF ORLANDO
283208081232101	D	217	12.0	120FLRD	CITY OF ORLANDO
283209081203201	U	908	12.0	120FLRD	CITY OF ORLANDO
283209081231401	D	757	12.0	120FLRD	CITY OF ORLANDO
283210081232401	D	438	20.0	120FLRD	CITY OF ORLANDO
283211081241001	D	150	12.0	120FLRD	ORLANDO
283213081205301	Z	885	36.0	120FLRD	ORLANDO UTIL
283216081230201	D	186	12.0	120FLRD	CITY OF ORLANDO
283216081244501	D	213	12.0	120FLRD	CITY OF ORLANDO
283217081225501	D	432	5.00	120FLRD	CITY OF ORLANDO
283217081231001	D	566	12.0	120FLRD	CITY OF ORLANDO
283217081232101	D	197	12.0	120FLRD	CITY OF ORLANDO
283217081275701	W	150	3.00	120FLRD	J MOORE
283218081214201	D	865	8.00	120FLRD	CITY OF ORLANDO
283218081214401	D	700	--	120FLRD	CITY OF ORLANDO
283218081214402	D	863	8.00	120FLRD	--
283218081214403	D	645	8.00	120FLRD	CITY OF ORLANDO
283218081224801	D	--	10.0	120FLRD	CITY OF ORLANDO
283218081231301	O	180	4	120FLRD	USGS
283218081244101	D	--	12.0	120FLRD	CITY OF ORLANDO
283219081215001	D	884	12.0	120FLRD	CITY OF ORLANDO
283219081220601	U	101	12.0	120FLRD	CITY OF ORLANDO
283220081225501	D	450	12.0	120FLRD	CITY OF ORLANDO
283220081234401	U	400	8.00	120FLRD	CITY OF ORLANDO
283222081204601	-	1250	--	--	ORLANDO UTILITIES
283222081283301	O	50.0	6.00	112NRSD	U S GEOL SURVEY
283223081211501	W	214	4.0	120FLRD	--
283223081220501	D	--	20.0	120FLRD	CITY OF ORLANDO

DATE: 05/17/93 EPA WELL REQUEST

SITE-ID	PRIMARY USE OF SITE	DEPTH OF WELL (FEET)	DIAMETER OF CASING (IN)	AQUIFER CODE	OWNER
283223081233801	D	--	6.00	120FLRD	CITY OF ORLANDO
283224081210201	W	1150	16.0	120FLRD	ORLANDO UTILITY
283224081221901	D	436	6.00	120FLRD	CITY OF ORLANDO
283224081222301	D	--	12.0	120FLRD	CITY OF ORLANDO
283224081232201	D	170	6.00	120FLRD	CITY OF ORLANDO
283225081205101	W	1250	26.0	120FLRD	ORLANDO UTILITY
283225081233601	D	--	10.0	120FLRD	CITY OF ORLANDO
283225081254801	W	140	3.00	120FLRD	EARL PARKER
283225081271001	U	566	10.0	120FLRD	SO GULF UTILITY
283225081271002	U	180	8.00	120FLRD	SO GULF UTIL
283226081214801	D	--	20.0	120FLRD	CITY OF ORLANDO
283227081205201	-	1150	--	--	ORLANDO UTILITIES
283227081221201	D	483	12.0	120FLRD	CITY OF ORLANDO
283227081230301	D	483	12.0	120FLRD	CITY OF ORLANDO
283227081275301	D	412	12.0	120FLRD	ORANGE COUNTY
283228081204201	W	1240	30.0	120FLRD	ORLANDO UTILITY
283230081235201	D	205	8.00	120FLRD	CITY OF ORLANDO
283232081224001	D	468	12.0	120FLRD	ORANGE COUNTY
283232081241201	D	382	12.0	120FLRD	CITY OF ORLANDO
283232081273201	W	355	8.00	120FLRD	ORANGE CO SCHOO
283233081212901	D	349	12.0	120FLRD	CITY OF ORLANDO
283233081213101	D	349	--	120FLRD	CITY OF ORLANDO
283233081224301	W	552	12.0	120FLRD	ORANGE COUNTY
283235081223500	O	18.0	2.00	--	--
283235081223601	O	18.0	2.00	--	--
283235081223610	-	4	--	--	--
283235081223801	D	325	6.00	120FLRD	SOUTHERN BELL
283235081223802	W	--	--	--	--
283235081223810	-	6	--	--	--
283235081224001	O	18.0	2.00	--	--
283235081224010	-	9	--	--	--
283235081224201	D	283	6.00	120FLRD	U S POST OFFICE
283235081231501	D	405	10.0	120FLRD	CITY OF ORLANDO
283236081225100	-	17	--	--	--
283236081225101	-	17	--	--	--
283236081225601	D	926	12.0	120FLRD	CITY OF ORLANDO
283237081223201	D	156	12.0	120FLRD	CITY OF ORLANDO
283237081232901	D	487	12.0	120FLRD	CITY OF ORLANDO
283237081235201	D	348	12.0	120FLRD	CITY OF ORLANDO
283237081254201	D	240	12.0	120FLRD	ORANGE COUNTY

DATE: 05/17/93

EPA WELL REQUEST

SITE-ID	PRIMARY USE OF SITE	DEPTH OF WELL (FEET)	DIAMETER OF CASING (IN)	AQUIFER CODE	OWNER
283240081221401	D	448	12.0	120FLRD	CITY OF ORLANDO
283240081225001	O	248	2.0	120FLRD	USGS
283240081225002	O	18.0	--	--	--
283240081225003	O	42.0	--	--	--
283240081225501	U	503	12.0	120FLRD	CITY OF ORLANDO
283240081230701	D	--	20.0	120FLRD	CITY OF ORLANDO
283240081232301	D	460	20.0	120FLRD	CITY OF ORLANDO
283240081232801	D	--	6.00	120FLRD	CITY OF ORLANDO
283240081243101	D	195	12.0	120FLRD	CITY OF ORLANDO
283241081213201	D	500	20.0	120FLRD	CITY OF ORLANDO
283241081221501	D	448	12.0	120FLRD	CITY OF ORLANDO
283241081231501	D	287	6.00	120FLRD	CITY OF ORLANDO
283242081200601	D	559	12.0	120FLRD	CITY OF ORLANDO
283242081224201	W	--	--	--	--
283242081225601	D	584	12.0	120FLRD	CITY OF ORLANDO
283242081225602	D	503	12.0	120FLRD	CITY OF ORLANDO
283242081233201	D	408	12.0	120FLRD	CITY OF ORLANDO
283242081245701	U	--	4.00	120FLRD	PHIL ROBERTS
283242081270701	D	380	4.00	120FLRD	PRESTIGE CORP
283242081270702	D	430	26.0	120FLRD	ORANGE COUNTY
283243081220801	O	205	--	--	--
283243081222301	D	471	20.0	120FLRD	CITY OF ORLANDO
283243081224101	W	290	6.00	120FLRD	U S POST OFFICE
283243081224701	U	250	12.0	120FLRD	TURNER & GEE CO
283243081230501	W	1050	12.0	120FLRD	FLA PUBLIC SER
283243081230701	D	192	6.00	120FLRD	FLA PUB SER CO
283243081260901	W	120	3.00	120FLRD	MRS EARL PARKER
283243081280901	W	405	8.00	120FLRD	SO STATES UTIL
			--	122HTRNN	--
283244081204301	D	1050	12.0	120FLRD	CITY OF ORLANDO
283244081232001	D	421	12.0	120FLRD	CITY OF ORLANDO
283244081243501	D	479	20.0	120FLRD	CITY OF ORLANDO
283244081274201	D	425	12.0	120FLRD	ORANGE COUNTY
283245081224601	D	470	12.0	120FLRD	CITY OF ORLANDO
283246081270401	-	1400	--	--	UTILITIES COMM. ORLANDO
283247081200801	D	518	12.0	120FLRD	CITY OF ORLANDO
283247081202201	D	688	20.0	120FLRD	CITY OF ORLANDO
283247081221501	D	548	6.00	120FLRD	CITY OF ORLANDO
283247081225601	D	254	20.0	120FLRD	CITY OF ORLANDO
283247081225701	D	--	8.00	120FLRD	CITY OF ORLANDO

DATE: 05/17/93 EPA WELL REQUEST

SITE-ID	PRIMARY USE OF SITE	DEPTH OF WELL (FEET)	DIAMETER OF CASING (IN)	AQUIFER CODE		OWNER
283247081261401	W	240	2.00	120FLRD	DR JOS SAFIAN	
283248081214601	D	231	12.0	120FLRD	CITY OF ORLANDO	
283249081205201	D	372	12.0	120FLRD	CITY OF ORLANDO	
283250081285801	O	180	6.00	120FLRD	U S GEOL SURVEY	
283250081285802	O	25.0	6.00	112NRSD	U S GEOL SURVEY	
283251081225501	D	196	12.0	120FLRD	CITY OF ORLANDO	
283251081271001	U	566	10.0	120FLRD	SO.GULF UTIL	
283251081271501	D	--	18.0	120FLRD	ORANGE COUNTY	
283252081223101	W	275	--	--		--
283252081283503	-	7	--	--		--
283253081222501	D	750	12.0	120FLRD	CITY OF ORLANDO	
283253081230901	D	461	12.0	120FLRD	CITY OF ORLANDO	
283253081275701	W	400	8.00	120FLRD	SOUTHERN GULF	
283253081283401	O	350	6.00	120FLRD	ORANGE CO	
			8.00	122HTRN		--
			--	112NRSD		--
283253081283402	S	20.0	6.00	112NRSD	USGS	
283253081283403	O	7.0	1.25	112NRSD	USGS	
283253081283404	U	33.0	1.25	112NRSD	U S GEOL SURVEY	
283253081283405	-	--	--	--		--
283254081232201	W	195	2.50	120FLRD	U S DEPT AGRIC	
283254081283701	W	272	8.00	120FLRD	ORANGE COUNTY	
283255081201601	D	449	12.0	120FLRD	CITY OF ORLANDO	
283255081205501	D	800	6.00	120FLRD	CITY OF ORLANDO	
283255081233601	D	352	12.0	120FLRD	CITY OF ORLANDO	
283256081233701	D	389	8.00	120FLRD	CITY OF ORLANDO	
283256081234001	D	507	12.0	120FLRD	CITY OF ORLANDO	
283257081210701	D	696	20.0	120FLRD	STATE ROAD DEPT	
283257081212301	D	528	18.0	120FLRD	CITY OF ORLANDO	
283257081213001	D	594	20.0	120FLRD	CITY OF ORLANDO	
283258081202101	D	312	12.0	120FLRD	CITY OF ORLANDO	
283258081204701	D	350	12.0	120FLRD	CITY OF ORLANDO	
283258081240901	D	669	20.0	120FLRD	CITY OF ORLANDO	
283300081224701	W	--	--	--		--
283300081233701	D	460	20.0	120FLRD	CITY OF ORLANDO	
283301081233201	D	--	6.00	120FLRD	CITY OF ORLANDO	
283302081204201	D	512	10.0	120FLRD	U.S.AIR FORCE	
283302081245801	D	183	--	--	ORANGE COUNTY	
283303081225301	D	460	8.00	120FLRD	CITY OF ORLANDO	
283303081232301	D	420	12.0	120FLRD	CITY OF ORLANDO	

DATE: 05/17/93 EPA WELL REQUEST

SITE-ID	PRIMARY USE OF SITE	DEPTH OF WELL (FEET)	DIAMETER OF CASING (IN)	AQUIFER CODE	OWNER
283303081255801	D	--	12.0	120FLRD	ORANGE COUNTY
283304081214701	D	550	20.0	120FLRD	CITY OF ORLANDO
283304081215301	D	--	12.0	120FLRD	CITY OF ORLANDO
283307081212001	D	--	6.00	120FLRD	CITY OF ORLANDO
283307081214701	D	495	10.0	120FLRD	CITY OF ORLANDO
283307081231501	D	--	8.00	120FLRD	CITY OF ORLANDO
283309081230001	W	300	4.00	120FLRD	--
283309081231401	D	--	10.0	120FLRD	CITY OF ORLANDO
283310081203801	D	620	12.0	120FLRD	STATE ROAD DEPT
283310081204001	D	550	12.0	120FLRD	STATE ROAD DEPT
283310081205401	D	530	12.0	120FLRD	STATE ROAD DEPT
283310081205901	W	--	--	120FLRD	COLONIAL, PLAZXA
283310081211801	D	260	12.0	120FLRD	CITY OF ORLANDO
283311081224001	D	424	12.0	120FLRD	CITY OF ORLANDO
283312081210301	D	349	6.00	120FLRD	C W JAMERSON
283313081201901	D	20.0	2.00	112NRSD	JOE H ZINK
283313081224001	D	130	6.00	120FLRD	CITY OF ORLANDO
283314081222201	D	--	8.00	120FLRD	CITY OF ORLANDO
283316081222601	W	1500	16.0	120FLRD	ORLANDO UTILITY
283317081220801	D	539	10.0	120FLRD	CITY OF ORLANDO
283317081223301	D	154	12.0	120FLRD	CITY OF ORLANDO
283317081243001	D	230	4.00	120FLRD	K-MART
			--	122HTRNS	--
283318081201801	U	245	4.00	120FLRD	ORANGE CO SCHOO
283318081222601	-	1500	--	--	ORLANDO UTILITIES
283320081211801	D	493	6.00	120FLRD	CITY OF ORLANDO
283321081231801	D	471	20.0	120FLRD	ORLANDO
283322081211401	D	557	20.0	120FLRD	CITY OF ORLANDO
283322081211601	D	496	8.00	120FLRD	CITY OF ORLANDO
283322081223001	D	--	6.00	120FLRD	CITY OF ORLANDO
283322081271001	-	1410	--	--	ORLANDO UTILITIES
283324081214501	D	219	12.0	120FLRD	CITY OF ORLANDO
283324081225001	W	160	5.00	120FLRD	SEYBOLD BAKING
283325081214301	D	313	12.0	120FLRD	CITY OF ORLANDO
283326081234601	D	456	18.0	120FLRD	FLORIDA DOT
283326081262101	D	109	18.0	120FLRD	CITY OF ORLANDO
283327081201201	D	431	10.0	120FLRD	U.S.AIR FORCE
283327081222901	-	1410	--	--	ORLANDO UTILITIES
283327081223201	W	1410	28.0	120FLRD	ORLANDO UTILITY
283327081241001	D	375	12.0	120FLRD	ORLANDO C CLUB

DATE: 05/17/93

EPA WELL REQUEST

SITE-ID	PRIMARY USE OF SITE	DEPTH OF WELL (FEET)	DIAMETER OF CASING (IN)	AQUIFER CODE	OWNER
283329081222601	W	695	26.0	120FLRD	ORLANDO UTILITI
283329081223701	W	450	26.0	120FLRD	ORLANDO UTILITY
283329081225001	D	582	12.0	120FLRD	CITY OF ORLANDO
283330081223401	D	410	12.0	120FLRD	ORLANDO UTILITY
283331081255701	U	525	10.0	120FLRD	SO STATES UTIL
283331081255702	U	345	8.00	120FLRD	SO STATES UTIL
283332081224901	D	384	12.0	120FLRD	CITY OF ORLANDO
283333081225001	D	410	10.0	120FLRD	CITY OF ORLANDO
283333081233501	O	1280	20.0	120FLRD	ORLANDO UTL COM
283333081233502	O	400	4.00	120FLRD	U S GEOL SURVEY
283334081225701	W	196	6.00	120FLRD	CENT CHRIST CHU
283334081243501	D	685	14.0	120FLRD	ORANGE COUNTY
283335081204501	U	655	4.00	120FLRD	CITY OF ORLANDO
283337081232301	D	228	18.0	120FLRD	CITY OF ORLANDO
283337081240801	W	649	6.00	120FLRD	ORLANDO CO CLUB
283337081242601	D	405	6.00	120FLRD	CITY OF ORLANDO
283338081204401	Z	828	6.00	120FLRD	USAF
283338081220701	W	1220	28.0	120FLRD	ORLANDO UTILITY
283338081222701	D	603	6.00	120FLRD	ATLANTIC CO
283339081202101	D	464	12.0	120FLRD	CITY OF ORLANDO
283339081210601	D	502	12.0	120FLRD	CITY OF ORLANDO
283339081270201	W	--	--	120FLRD	ORLANDO UTILITI
283340081213601	-	1220	--	--	UTILITIES ORLANDO
283340081222501	D	550	6.00	120FLRD	ATLANTIC CO
283340081222801	O	2090	4.0	--	SJRWMD
283340081222802	O	1350	8.00	--	SJRWMD
283340081222803	O	450	16	--	SJRWMD
283340081235601	D	--	6.00	120FLRD	ORLANDO C CLUB
283342081204301	D	482	8.00	120FLRD	U.S.AIR FORCE
283343081215801	W	1350	28.0	120FLRD	ORLANDO UTILITY
283344081260501	D	383	16.0	120FLRD	ORANGE COUNTY
283346081222501	W	1160	28.0	120FLRD	ORLANDO UTILITY
283348081204601	Z	453	6.00	120FLRD	CITY OF ORLANDO
283348081204602	Z	1000	6.00	120FLRD	CITY OF ORLANDO
283348081213601	-	1410	--	--	UTILITIES ORLANDO
283348081215301	-	1160	--	--	UTILITIES COMM. ORLANDO
283348081215801	-	1350	--	--	UTILITIES ORLANDO
283348081240201	W	200	4.00	120FLRD	MELWEB SIGN CO
			--	122HTRNS	--
283350081215201	D	469	12.0	120FLRD	CITY OF ORLANDO

DATE: 05/17/93

EPA WELL REQUEST

SITE-ID	PRIMARY USE OF SITE	DEPTH OF WELL (FEET)	DIAMETER OF CASING (IN)	AQUIFER CODE	OWNER
283350081215401	W	300	4.00	120FLRD	POLAR WATER CO
283351081220701	W	1410	28.0	120FLRD	ORLANDO UTILITY
283351081224701	D	415	--	120FLRD	CITY OF ORLANDO
283353081204801	D	478	18.0	120FLRD	CITY OF ORLANDO
283353081222401	W	1440	28.0	120FLRD	ORLANDO UTILITY
283354081231501	W	157	6.00	120FLRD	J.HELLER
			--	122HTRNS	GEO.TERRY,SR.
283354081235401	D	606	20.0	120FLRD	CITY OF ORLANDO
283354081283701	W	160	4.00	120FLRD	HIAWASSE RD CHA
283356081211501	D	524	12.0	120FLRD	CITY OF ORLANDO
283357081272201	W	1410	16.0	120FLRD	ORLANDO UTILITY
283358081211501	D	573	12.0	120FLRD	CITY OF ORLANDO
283358081272901	D	--	20.0	120FLRD	ORANGE COUNTY
283401081212101	W	350	4.00	120FLRD	--
283402081211001	D	728	12.0	120FLRD	CITY OF ORLANDO
283402081211501	D	462	12.0	120FLRD	CITY OF ORLANDO
283402081222801	-	1440	--	--	UTILITIES ORLANDO
283404081212001	D	485	12.0	120FLRD	W C PHILLIPS
283404081222401	Z	--	--	120FLRD	N R KEMP
283404081272001	-	1400	--	--	ORLANDO UTILITIES
283406081210801	D	--	6.00	120FLRD	ORANGE COUNTY
283407081272201	W	1400	16.0	120FLRD	ORLANDO UTILITY
283408081233701	D	454	10.0	120FLRD	CITY OF ORLANDO
283408081235301	D	--	10.0	120FLRD	CITY OF ORLANDO
283409081223501	O	11.0	2.00	--	--
283409081223502	O	24.0	2.00	--	--
283410081204701	D	437	10.0	120FLRD	ORANGE COUNTY
283410081220601	D	433	8.00	120FLRD	CITY OF ORLANDO
283410081242301	W	680	16.0	120FLRD	DR PHILLIPS
			--	122HTRNN	--
283410081272701	W	470	8.00	120FLRD	SIL PINES GOLF
283410081272702	W	360	6.00	120FLRD	SIL PINE GOLF
283411081223501	O	13.0	--	--	--
283411081223502	O	16.0	2.00	--	--
283411081223503	O	13.0	2.00	--	--
283411081223510	O	24.0	2.00	--	--
283411081223511	O	24.0	2.00	--	--
283412081223501	O	13.0	2.00	--	--
283412081223502	O	19.0	2.00	--	NONE
283412081223503	O	16.0	2.00	--	--

DATE: 05/17/93 EPA WELL REQUEST

SITE-ID	PRIMARY USE OF SITE	DEPTH OF WELL (FEET)	DIAMETER OF CASING (IN)	AQUIFER CODE	OWNER
283413081223500	O	13.0	2.00	--	--
283414081223601	-	20	--	--	--
283414081283301	U	200	10.0	120FLRD	SO GULF UTIL
283415081233801	D	407	12.0	120FLRD	CITY OF ORLANDO
283415081235201	D	405	12.0	120FLRD	CITY OF ORLANDO
283418081222801	D	414	10.0	120FLRD	CITY OF ORLANDO
283418081240101	D	387	8.00	120FLRD	NELLIE B FORBES
283421081214701	D	596	8.00	120FLRD	CITY OF ORLANDO
283421081214901	D	578	12.0	120FLRD	CITY OF ORLANDO
283423081241701	W	1230	8.00	120FLRD	MINUTE MAID
283426081203101	D	425	12.0	120FLRD	ORANGE COUNTY
283428081224901	D	500	20.0	120FLRD	CITY OF ORLANDO
283428081225201	D	--	20.0	120FLRD	CITY OF ORLANDO
283428081230201	D	174	12.0	120FLRD	CITY OF ORLANDO
283428081230202	D	405	20.0	120FLRD	CITY OF ORLANDO
283428081274801	W	230	4.00	120FLRD	WHOO RADIO
			--	122HTRNN	--
283429081221901	D	451	20.0	120FLRD	CITY OF ORLANDO
283430081222401	D	495	12.0	120FLRD	CITY OF ORLANDO
283431081223501	D	431	12.0	120FLRD	CITY OF ORLANDO
283432081284901	W	460	10.0	120FLRD	SIL STAR MA PK
283433081284201	W	369	8.00	120FLRD	SILVER STAR TP
283434081225401	D	--	10.0	120FLRD	UNKNOWN PRIVATE
283434081241901	D	--	--	120FLRD	ORANGE COUNTY
283435081222001	D	408	12.0	120FLRD	CITY OF ORLANDO
283435081252301	D	123	8.00	120FLRD	ORANGE COUNTY
283437081221901	O	400	--	120FLRD	FLA.HOSP
283437081260501	U	450	6.00	120FLRD	SOUTHERN GULF U
283438081251801	W	310	2.00	120FLRD	FRED EWEN
283439081222301	D	409	12.0	120FLRD	CITY OF ORLANDO
283439081252601	W	140	3.00	120FLRD	BANDYS DAIRY
283439081272101	D	260	4.00	120FLRD	ORANGE COUNTY
283439081272102	D	375	12.0	120FLRD	ORANGE COUNTY
283441081203301	W	1300	10.0	120FLRD	FLA UTILITIES
283441081230801	D	456	18.0	120FLRD	CITY OF ORLANDO
283441081251501	D	199	8.00	120FLRD	ORANGE COUNTY
283442081260671	-	8	--	--	--
283442081260672	-	12	--	--	--
283442081260673	-	10	--	--	--
283442081260674	-	12	--	--	--

DATE: 05/17/93

EPA WELL REQUEST

SITE-ID	PRIMARY USE OF SITE	DEPTH OF WELL (FEET)	DIAMETER OF CASING (IN)	AQUIFER CODE		OWNER
283442081260675	-	12	--	--		--
283442081260676	-	10	--	--		--
283442081260677	-	10	--	--		--
283442081260678	-	10	--	--		--
283444081231301	D	300	6.00	120FLRD	DUBSDREAD CLUB	
283444081281801	W	155	6.00	122HTRNN	SOUTHERN GULF	
283445081223801	D	439	20.0	120FLRD	ORLANDO	
283445081225201	D	439	10.0	120FLRD	CITY OF ORLANDO	
283445081250101	D	416	12.0	120FLRD	ORANGE COUNTY	
283446081225901	D	418	20.0	120FLRD	CITY OF ORLANDO	
283446081284701	W	406	10.0	120FLRD	MCALLISTER GROV	
			--	122HTRNN		--
283447081214001	D	120	3.00	120FLRD	ROBT J CANNON	
283447081241701	D	400	12.0	120FLRD	ORANGE COUNTY	
			--	122HTRNN		--
283448081272201	W	150	4.00	122HTRNN	FRED SCHILLING	
283449081230301	D	203	12.0	120FLRD	CITY OF ORLANDO	
283453081223401	D	375	12.0	120FLRD	CITY OF ORLANDO	
283455081230301	D	--	--	120FLRD	DUBSDREAD CLUB	
283458081231401	W	280	6.00	120FLRD	DUBSDREAD CLUB	
283502081280801	U	73.0	4.00	122HTRNS	SO GULF UTIL	
283502081280802	W	200	4.00	120FLRD	SO GULF UTIL	
283503081203701	Z	--	--	--		--
283505081223201	D	--	10.0	120FLRD	ORANGE COUNTY	
283505081245401	-	170	--	--		--
283506081202201	Z	--	--	--		--
283508081270801	D	341	12.0	120FLRD	ORANGE COUNTY	
283514081222301	D	250	12.0	120FLRD	ORANGE COUNTY	
283516081245101	Z	170	8.00	120FLRD	SHADER BROS	
283516081245701	W	190	--	122HTRNS	WOMETCO VENDING	
283518081274301	W	100	6.00	122HTRNN	CENT FLA UTIL	
283518081274302	W	--	--	122HTRNN	CENT FLA UTIL	
283520081241501	D	260	12.0	120FLRD	NYDEGGER CO	
283521081231101	D	450	12.0	120FLRD	ORANGE COUNTY	
283521081245801	U	205	4.00	122HTRNN	ACTION LEASING	
283522081221001	D	--	12.0	120FLRD	ORANGE COUNTY	
283523081202701	Z	--	--	--		--
283525081210001	Z	--	--	--		--
283527081201001	Z	--	--	--		--
283528081235201	D	745	12.0	120FLRD	ORANGE COUNTY	

DATE: 05/17/93

EPA WELL REQUEST

SITE-ID	PRIMARY USE OF SITE	DEPTH OF WELL (FEET)	DIAMETER OF CASING (IN)	AQUIFER CODE	OWNER
283529081232801	D	396	18.0	120FLRD	FLA DOT
283529081253201	W	364	8.00	120FLRD	ROSEMONT C CLUB
283530081214001	D	--	--	120FLRD	WINTER PARK
283530081214301	D	372	12.0	120FLRD	WINTER PARK
283531081254201	-	365	--	--	--
283532081251001	W	364	8.00	120FLRD	ROSEMONT C CLUB
283532081273401	D	341	12.0	120FLRD	ORANGE COUNTY
283535081214201	-	--	--	--	WINTER PARK AND OTHERS
283535081244801	T	160	6.00	120FLRD	ORLANDO UTILITI
			--	122HTRNN	--
283535081265901	D	325	12.0	120FLRD	ORANGE COUNTY
283535081265902	Z	375	6.00	120FLRD	ORANGE COUNTY
283535081265903	T	350	3.00	120FLRD	ORANGE COUNTY
283537081202401	Z	--	--	--	--
283537081204101	Z	--	--	--	--
283537081272201	U	415	8.00	120FLRD	SO STATES UTIL
283538081283501	U	240	4.00	120FLRD	J ARRA
283540081252301	D	--	12.0	120FLRD	ORANGE COUNTY
283540081283201	W	358	8.00	120FLRD	J M KNOX
283540081283301	O	300	4.00	120FLRD	U S GEOL SURVEY
283544081251001	W	250	4.00	120FLRD	R P EUNICE
283545081214701	D	507	20.0	120FLRD	WINTER PARK
283545081244901	D	721	12.0	120FLRD	CITY OF ORLANDO
283545081273901	W	595	16.0	122HTRNN	ORANGE CO
			--	120FLRD	SO STATES UTIL
283546081223201	D	390	20.0	120FLRD	ORANGE COUNTY
283546081283501	W	300	3.00	120FLRD	ORANGE COUNTY
283547081202201	Z	--	--	--	--
283547081210101	D	400	10.0	120FLRD	WINTER PARK
283547081273901	W	225	12.0	120FLRD	SO STATES UTIL
			--	122HTRNN	--
283548081211201	D	300	6.00	120FLRD	WINT PK TELEPHO
283548081224601	D	400	20.0	120FLRD	ORANGE COUNTY
283548081234401	D	150	4.00	120FLRD	ST MARKS CHURCH
283549081203201	Z	--	--	--	--
283550081214401	D	350	8.00	120FLRD	WINTER PARK
283551081250601	W	345	--	120FLRD	E O GUNTER
283553081214701	D	380	8.00	120FLRD	ST OF FLORIDA
283553081215101	W	300	10.0	120FLRD	ST OF FLORIDA
283553081250401	W	180	3.00	120FLRD	FISKE & GAY

DATE: 05/17/93

EPA WELL REQUEST

SITE-ID	PRIMARY USE OF SITE	DEPTH OF WELL (FEET)	DIAMETER OF CASING (IN)	AQUIFER CODE	OWNER
283556081273401	T	500	6.00	120FLRD	ORANGE COUNTY
283557081231301	D	376	12.0	120FLRD	ORANGE COUNTY
283559081240601	D	--	10.0	120FLRD	ORANGE COUNTY
283600081205001	Z	--	--	--	--
283600081212701	-	451	--	--	GENERALS WATERWORKS
283600081212702	-	460	--	--	GENERAL WATERWORKS
283601081210801	W	487	8.00	120FLRD	GEN WTRWKS
283602081251001	W	289	4.00	120FLRD	T G LEE DAIRY
283602081252201	D	142	6.00	120FLRD	ORANGE COUNTY
283602081252401	-	142	--	--	--
283607081211301	W	451	12.0	120FLRD	GEN.WATRWKS
283608081211601	W	460	16.0	120FLRD	GEN.WTRWKS
283608081273101	D	341	12.0	120FLRD	ORANGE COUNTY
283610081204501	Z	--	--	--	--
283616081215101	D	320	6.00	120FLRD	WINTER PARK
283617081200902	Z	--	--	--	--
283621081221801	D	--	12.0	120FLRD	FLORIDA DOT
283623081230501	W	1270	16.0	120FLRD	GEN.WTRWKS
283624081253801	D	--	13.0	120FLRD	ORANGE COUNTY
283625081203501	Z	--	--	--	--
283626081241701	D	--	10.0	120FLRD	ORANGE COUNTY
283630081205401	Z	--	--	--	--
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			--	122HTRNS	--
283637081200901	D	330	8.00	120FLRD	WINTER PARK
283637081215201	D	400	12.0	120FLRD	WINTER PARK
			--	122HTRN	--
283637081285301	W	250	6.00	120FLRD	CENT FLA UTIL
283637081285302	W	215	4.00	120FLRD	CENT FLA UTIL
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283642081211101	Z	--	--	--	--
283642081254301	W	392	6.00	120FLRD	LEHIGH CEMENT
283643081215701	D	977	--	120FLRD	FLORIDA DOT
283647081212301	Z	--	--	--	--
283648081254301	W	390	8.00	120FLRD	LEHIGH CEMENT
283649081283601	O	365	4.00	120FLRD	U S GEOL SURVEY
283653081283301	Z	320	4.00	120FLRD	ORANGE COUNTY
283654081260801	D	365	18.0	120FLRD	ORANGE COUNTY
283655081262001	W	1000	4.00	120FLRD	SO STATES UTIL

DATE: 05/17/93 EPA WELL REQUEST

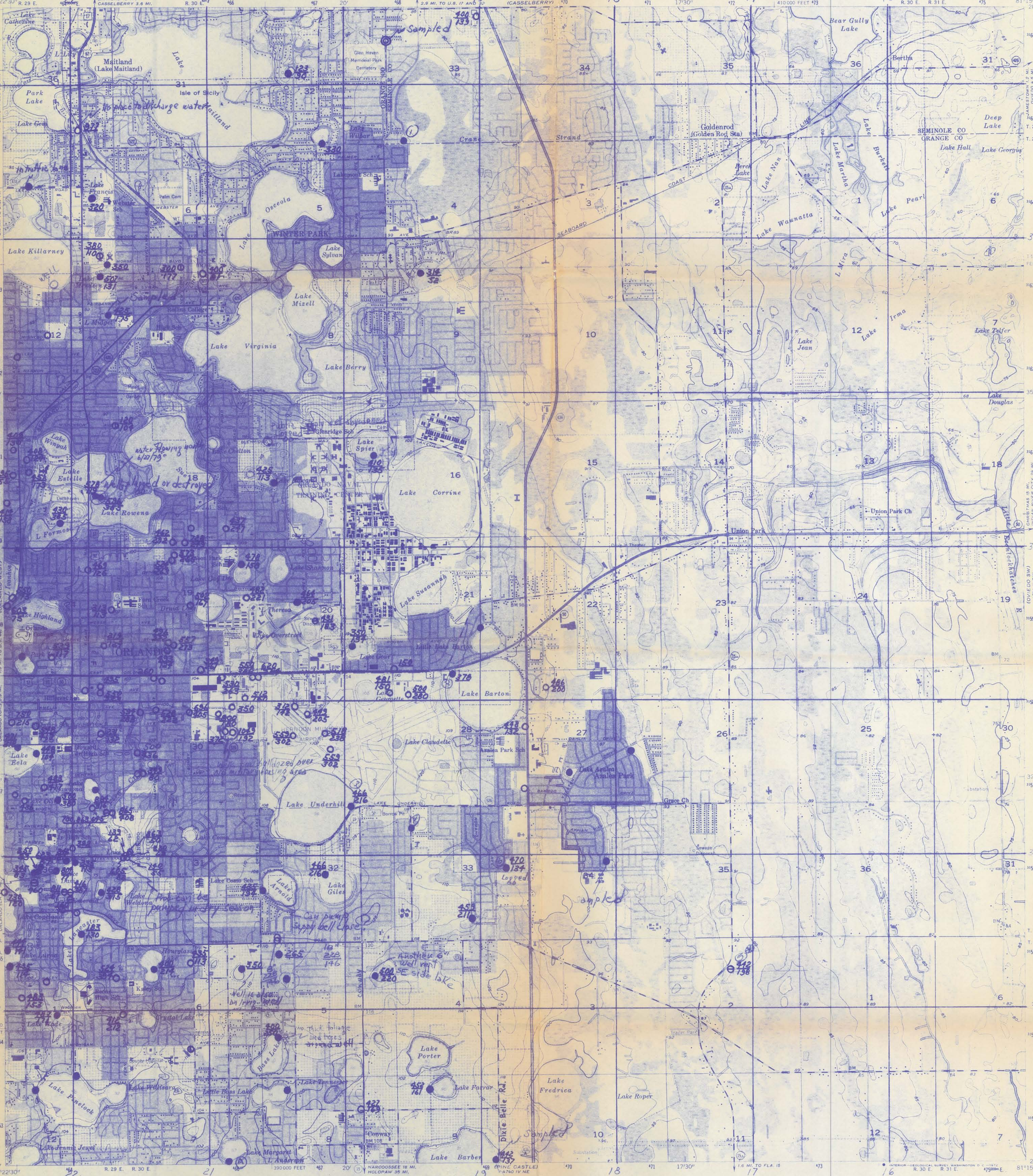
SITE-ID	PRIMARY USE OF SITE	DEPTH OF WELL (FEET)	DIAMETER OF CASING (IN)	AQUIFER CODE		OWNER
283655081262002	U	--	--	120FLRD	SO STATES UTIL	
283655081283401	D	301	20.0	120FLRD	ORANGE CO.	
283656081264501	U	200	6.00	120FLRD	SO STATES UTIL	
283657081230401	W	380	8.00	120FLRD	ORANGE CO SCHOO	
283658081254801	U	302	--	120FLRD	SOUTHERN STATES	
			--	122HTRNS		--
283702081203701	Z	--	--	--		--
283702081264601	D	682	12.0	120FLRD	ORANGE COUNTY	
283702081265801	U	232	12.0	120FLRD	SOUTHERN STATES	
283703081225001	W	371	--	120FLRD	CITY OF EATONVI	
283704081202401	D	--	4.00	120FLRD	ORANGE COUNTY	
283704081224901	W	341	12.0	120FLRD	CITY OF EATONVI	
			--	122HTRNN		--
283706081271801	D	380	20.0	120FLRD	ORANGE COUNTY	
283706081271802	T	290	6.00	120FLRD	WISE BROTHERS	
283707081250901	W	363	8.00	120FLRD	SOUTHERN STATES	
283707081250902	W	350	6.00	120FLRD	SO STATES UTIL	
283708081263001	W	180	4.00	120FLRD	CHILD CARE CENT	
			--	122HTRNS		--
283708081263002	W	--	2.00	120FLRD	CHILD CARE CENT	
283709081263701	W	148	4.00	120FLRD	DRY WALL SERVIC	
			--	122HTRNS		--
283713081214701	Z	--	--	--		--
283723081210201	Z	--	--	--		--
283723081263201	W	400	10.0	120FLRD	LOCKHART ELEMEN	
283729081223801	D	403	20.0	120FLRD	CITY OF MAITLAN	
283729081273701	U	400	6.00	120FLRD	SO STATES UTIL	
			--	122HTRN		--
283729081273702	U	200	4.00	120FLRD	SO STATES UTIL	
			--	--	ORANGE CO	
283735081224001	D	371	12.0	120FLRD	ORANGE CO	
			--	122HTRN		--
283742081270101	W	325	4.00	120FLRD	LOGAN LIFTS	
283743081214501	W	390	8.00	120FLRD	MAITLAND	
283743081253701	D	--	12.0	120FLRD	ORANGE COUNTY	
283750081224801	O	19.0	1.25	120NRSD	U S GEOL SURVEY	
283753081224801	O	18.0	1.25	112NRSD	U S GEOL SURVEY	
283758081223801	-	8	--	--		--
283806081252401	W	364	10.0	120FLRD	PADAWER BURL	
			--	--	ORANGE COUNTY	

DATE: 05/17/93 EPA WELL REQUEST

SITE-ID	PRIMARY USE OF SITE	DEPTH OF WELL (FEET)	DIAMETER OF CASING (IN)	AQUIFER CODE	OWNER
283807081203401	W	430	12.0	120FLRD	MAITLAND
283809081233801	W	--	--	120FLRD	MAITLAND CITY OF
283809081251801	T	200	4.00	120FLRD	ECOLOGICAL UTIL
283809081251802	W	571	8.00	120FLRD	ECOLOGICAL UTIL
			--	--	ORANGE COUNTY
283815081215702	-	8	--	--	--
283816081225501	T	374	4.00	120FLRD	ORANGE COUNTY
283816081225502	D	385	12.0	120FLRD	ORANGE COUNTY
283822081210701	W	--	6.00	120FLRD	MAITLAND UTIL
283824081221503	-	6	--	--	--
283827081215501	W	227	4.00	120FLRD	R E MCCANNA
283829081220401	W	361	6.00	120FLRD	WINTER P LAND
283829081275101	W	370	6.00	120FLRD	H P MUFURD
283830081230101	D	182	10.0	120FLRD	HANS SCHWEIZER

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

ORLANDO EAST QUADRANGLE
FLORIDA
7.5 MINUTE SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USGS, USC&GS, and Florida Geodetic Survey

Culture and drainage in part compiled from aerial photographs taken 1954. Topography by planetable surveys 1956

Polyconic projection. 1927 North American datum
10,000-foot grid based on Florida coordinate system, east zone
1000-meter Universal Transverse Mercator grid ticks, zone 17, shown in blue

Red tint indicates areas in which only landmark buildings are shown

Revisions shown in purple compiled from aerial photographs taken 1970. This information not field checked

Purple tint indicates extension of urban areas

AC
LL
St. + storm
Cooling
Sewage + waste

UTM GRID AND 1970 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 5 FEET
DATUM IS MEAN SEA LEVEL

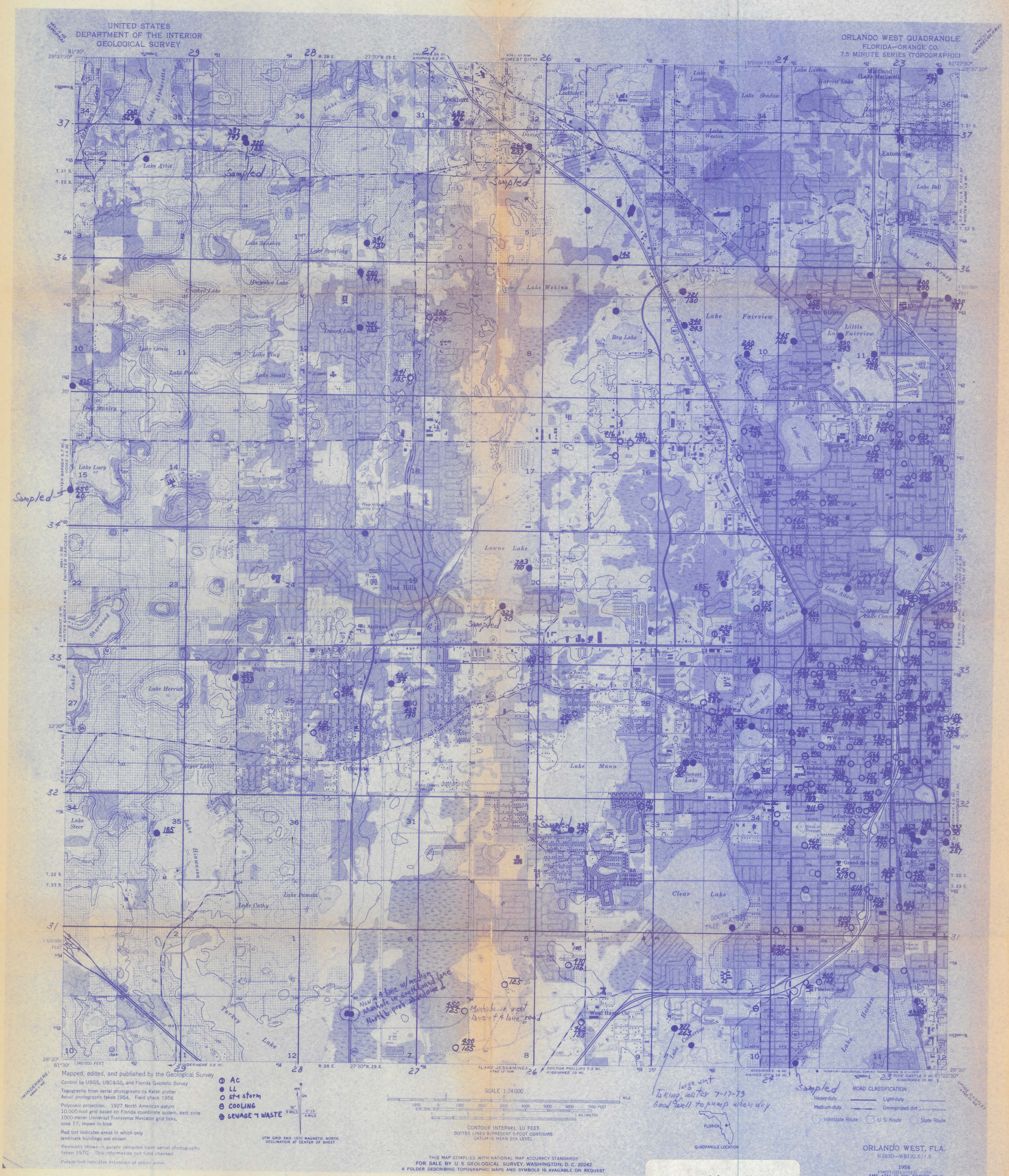
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, WASHINGTON, D. C. 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

FLORIDA
QUADRANGLE LOCATION

ROAD CLASSIFICATION

Heavy-duty		Light-duty	
Medium-duty		Unimproved dirt	
U. S. Route		State Route	

ORLANDO EAST, FLA.
N2830—W8115/7.5
1956
PHOTOREVISED 1970
AMS 4741 III SE—SERIES V847



Reference 26

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV

345 COURTLAND STREET, N.E.
ATLANTA, GEORGIA 30365

TELEPHONE MEMORANDUM

CALL MADE BY: Cynthia K. Gurley
DATE OF CALL: June 7, 1993
TIME OF CALL: 0945

SIGNATURE/DATE: Cynthia K. Gurley 6-7-93
FACILITY: Chevron Chemical Co.
EPA ID No.: FLD004064242

PERSON CONTACTED: Ms. Anne Bradner
TITLE/POSITION: Hydrogeologist
ORGANIZATION: United States Department of Interior
TELEPHONE NUMBER: ~~(704)~~ 407 648-6191

SUBJECT: To clarify the legend on the drainage well maps Ms. Bradner sent to EPA.

SUMMARY OF CONVERSATION:

Type of drainage wells:

AC = closed water cooled air conditioner wells. Overland runoff can not flow into this type of well.

LL = lake overflow wells. These wells are open to overland drainage.

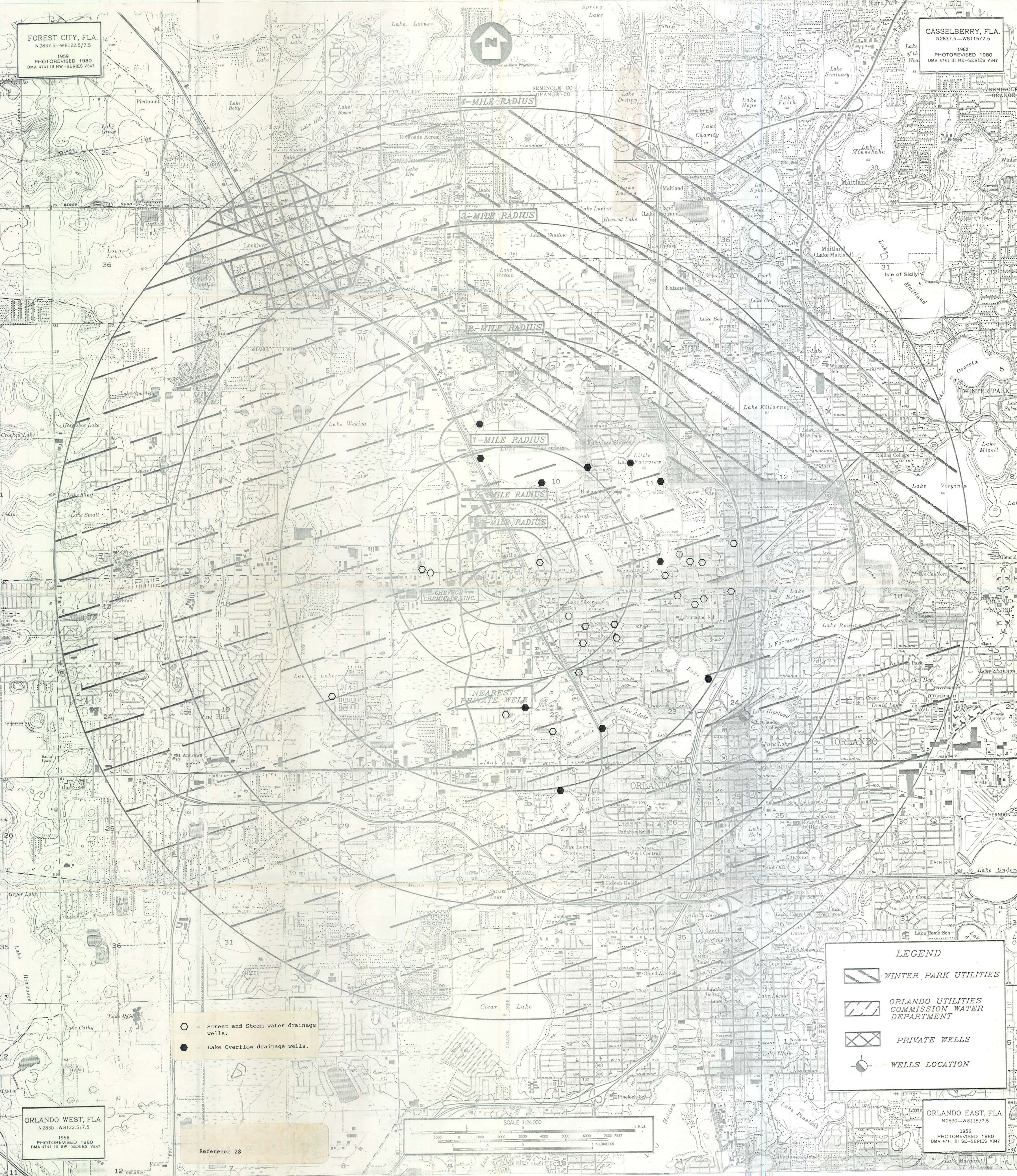
STA STORM = street and storm water drainage wells. These wells are open to overland drainage.

COOLING = wells are used for cooling purposes only. These type wells are closed and do not permit overland runoff into the well.

SEWAGE & WASTE = most of these wells were either closed in the 40s or changed into storm water wells. The map does not indicate which wells are closed and which wells are still used as storm wells.

DATE OF CALL: June 7, 1993
TIME OF CALL: 1430

I asked Ms. Bradner to explain the installation and depth of the drainage wells which are located on maps in Reference 26. Each well will have the total depth and casing depth beside it, if known, on the map. The total depth is the exact depth that was drilled for the well. The casing depth is the depth of the casing from surface. There are no screens, the casing is left open at the bottom and overland drainage flows through the casing and drops into the open well. The well is held open by limestone. The wells are drilled into the Floridan aquifer.



FOREST CITY, FLA.
N2837.5—W8122.5/7.5
1959
PHOTOREVISED 1980
DMA 4741 III NW—SERIES V847
CASSELBERRY, FLA.
N2837.5—W8115/7.5
1962
PHOTOREVISED 1980
DMA 4741 III NE—SERIES V847
ORLANDO WEST, FLA.
N2830—W8122.5/7.5
1956
PHOTOREVISED 1980
DMA 4741 III SW—SERIES V847
ORLANDO EAST, FLA.
N2830—W8115/7.5
1956
PHOTOREVISED 1980
DMA 4741 III SE—SERIES V847
4-MILE RADIUS
3-MILE RADIUS
2-MILE RADIUS
1-MILE RADIUS
NEAREST PRIVATE WELL
CHEVRON CHEMICALS, INC.
LEGEND
WINTER PARK UTILITIES
ORLANDO UTILITIES COMMISSION WATER DEPARTMENT
PRIVATE WELLS
WELLS LOCATION
= Street and Storm water drainage wells.
= Lake Overflow drainage wells.
SCALE 1:24 000
Reference 28
ORLANDO
WINTER PARK
Maitland
Eatonville
Lockhart
Lake Killarney
Lake Fairview
Lake Adair
Lake Wekiva
Clear Lake

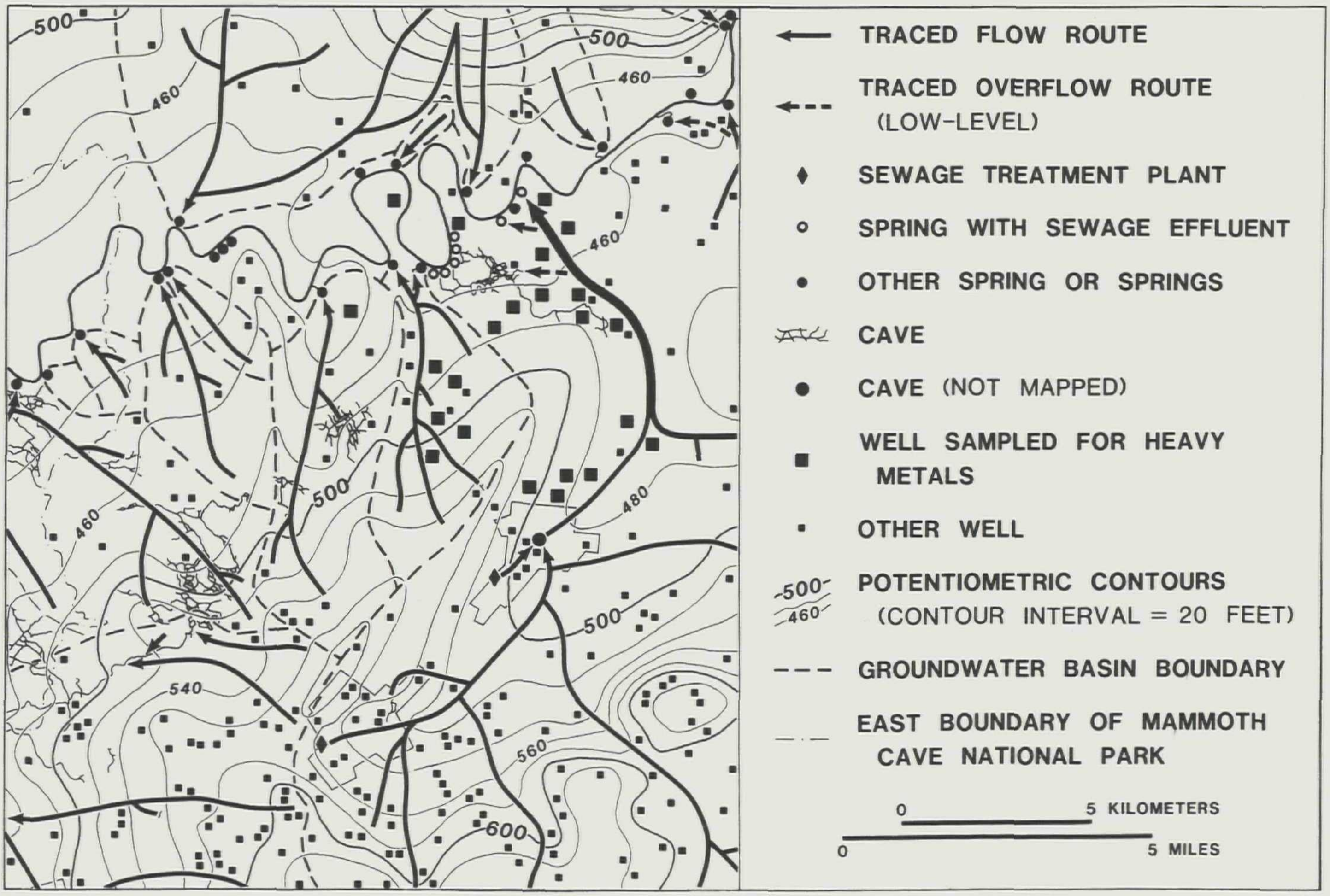
United States
Environmental Protection
Agency

Region 4
345 Courtland Street, NE
Atlanta, GA 30365

EPA 904/6-88-001
October 1988

REFERENCE 29

APPLICATION OF DYE-TRACING TECHNIQUES FOR DETERMINING SOLUTE-TRANSPORT CHARACTERISTICS OF GROUND WATER IN KARST TERRANES



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV

345 COURTLAND STREET
ATLANTA, GEORGIA 30365

Application Of Dye-Tracing Techniques For Determining Solute-Transport Characteristics Of Ground Water In Karst Terranes

Prepared By

U.S. Environmental Protection Agency
Ground-Water Protection Branch
Region IV - Atlanta, Georgia

and

U.S. Geological Survey
Water Resources Division
Kentucky District
Louisville, Kentucky

Approximately 20% of the United States is underlain by karst aquifers. This approximation includes roughly 50% of both Kentucky and Tennessee, substantial portions of northern Georgia and Alabama, and parts of other Region IV states. The prevalence of karst aquifers in the southeast, the common use of karst aquifers as drinking water sources and the vulnerability of these aquifers to contamination highlighted the need to provide a mechanism to assist in ground-water management and protection in karst terranes. In an attempt to meet this need, the U.S. Environmental Protection Agency (EPA) - Region IV and the Kentucky District of the U.S. Geological Survey (USGS), have been cooperating to document the application of dye tracing techniques and concepts to ground-water protection in karst aquifers. I am pleased to announce that these efforts have resulted in the preparation of this manual, entitled, "Application Of Dye-Tracing Techniques For Determining Solute-Transport Characteristics Of Ground Water In Karst Terranes." The information presented herein should be viewed as another analytical "tool" to assist in the management and protection of karst water supplies.

Joe R. Franzmathes for
Greer C. Tidwell
Regional Administrator

SEP 27 1988
Date

APPLICATION OF DYE-TRACING TECHNIQUES FOR DETERMINING SOLUTE-TRANSPORT CHARACTERISTICS OF GROUND WATER IN KARST TERRANES

By D.S. Mull, T.D. Liebermann, J.L. Smoot, and L.H. Woosley, Jr.

ABSTRACT

Some of the most serious incidents of ground-water contamination, nationwide, have been reported in karst terranes. Karst terranes are characterized by sinkholes; karst windows; springs; caves; and losing, sinking, gaining, and underground streams. These karst features are environmentally significant because they are commonly directly connected to the ground-water system. If these ground-water systems are used as a drinking water source, their environmental significance is increased. Sinkholes are especially significant because they can funnel surface runoff to the ground-water system. Thus, any pollutant carried by surface runoff across a karst terrane has the potential for rapid transport to the ground-water system.

Because of the extreme vulnerability of karst ground-water systems to contamination, water-management and protection agencies need an understanding of the occurrence of ground water, including the extent of the recharge areas for specific karst aquifers, a knowledge of the inherent vulnerabilities of the systems, and an understanding of the characteristics of pollutant transport within the systems. To provide water managers (those responsible for providing and managing water supplies) and protection agencies (those responsible for regulating water supplies and water quality) with a tool for the management and protection of their karst water resources, the U.S. Geological Survey in cooperation with Region IV of the U.S. Environmental Protection Agency has prepared this manual to illustrate the application of dye-tracing results and the related predictive techniques that could be used for the protection of ground-water supplies in karst terrane. This manual will also be useful for State and local agencies responsible for implementing Wellhead Protection Programs pursuant to the Safe Drinking Water Act as amended in 1986.

This manual includes a brief review of karst hydrogeology, summarizes dye-tracing concepts and selected techniques, lists sources for equipment and materials, and includes an extensive list of references for more detailed information on karst hydrogeology and on various aspects of dye tracing in karst terrane. Both qualitative and quantitative dye-tracing techniques are described and quantitative analyses and interpretation of dye-trace data are demonstrated.

Qualitative dye tracing with various fluorescent dyes and passive dye detectors, consisting of activated coconut charcoal or surgical cotton, can be used to identify point-to-point connections between points of ground-water recharge, such as sinkholes, sinking streams, and karst windows and discharge points, such as water-supply springs and wells. Results of qualitative tracing can be used to confirm the direction of ground-water flow inferred

from water-level contour maps, and to help delineate the recharge area draining to a spring or well. Qualitative dye tracing is, generally, the first step in the collection and interpretation of quantitative dye trace data.

Quantitative dye tracing usually requires automatic samplers, discharge measurements at the ground-water resurgence, and fluorometric or spectrofluorometric analysis to quantify passage of the dye cloud. These results can be used to determine solute-transport characteristics such as traveltime for arrival of the leading edge of the dye cloud, peak dye concentration, trailing edge, and persistence of the dye cloud at the discharge point, which may be a spring or well used for public water supply.

Repeated quantitative dye traces between the same recharge and discharge points, under different flow conditions, can be used to develop predictive relations between ground-water discharge, apparent ground-water flow velocity, and solute-transport characteristics. Normalized peak-solute concentration, mean traveltime, and standard deviation of time of travel can be used to produce a composite, dimensionless recovery curve that is used to simulate solute-transport characteristics for selected discharges. Using this curve and previously developed predictive relations, a water manager can estimate the arrival time, peak concentration, and persistence of a soluble conservative contaminant at a supply spring or well, on the basis of discharge and the quantity of spilled contaminant.

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1. INTRODUCTION

1.1 Background

The primary objective of the manager of a public water-supply system is to provide the consumer with a safe, dependable supply of drinking water. In large areas of many states, ground water is the exclusive or primary source of drinking water. Often, disinfection is the only treatment used to meet applicable public drinking-water standards. However, reports of ground-water contamination nationwide, combined with increasing dependence on ground water, have led to a growing awareness of the potential for degradation of this valuable source of drinking water.

Almost all ground water is vulnerable to contamination, whether the contamination is caused by natural geologic or hydrologic conditions or by man's activities. Karst ground-water supplies are particularly vulnerable to contamination because of the relatively direct connection to surface activities and the rapid transport of surface runoff and contaminants to karst ground-water systems. The potential for contamination of karst ground-water systems from man-made sources is particularly great where urban areas and major transportation corridors are built in the recharge areas of karst aquifers.

Karst terrane is characterized by surface and subsurface features, such as sinkholes; karst windows; springs; caves; and losing, sinking, gaining and underground streams. Sinkholes are environmentally significant land forms because they can provide a direct path for surface runoff to recharge karst aquifers. They commonly lead directly to the aquifer system through pipe-like openings in residuum and bedrock. Some sinkholes may also act as collection and retention basins for surface runoff. Thus, depending upon the size of the area draining to the sinkhole and the nature of the subsurface openings, relatively large quantities of water may enter the aquifer system in a short period of time. Where sinkholes occur, any pollutant carried by surface runoff has the potential for rapid transport to ground water.

Public water-supplies in karst terranes may be more vulnerable to detrimental effect than nonkarst, ground-water supplies. Because of the variability of soil cover and the likelihood of overlying soils being shallow or absent in karst areas, the potential exists for little or no enhancement of water quality before surface water is recharged to the aquifer system. Also, pollutant traveltime in a karst aquifer can be rapid, on the order of miles per day in contrast to feet per year in most non-karst aquifers. Therefore, the managers of a water supply derived from ground water in a karst terrane need to have a detailed understanding of the extent of the aquifer recharge area, a knowledge of the inherent vulnerabilities of the aquifer, and an understanding of how pollutants move through the system. Accordingly, specialized qualitative techniques are required to delineate the recharge areas of karst aquifer and to identify continuity between potential recharge and discharge points of aquifers. In addition, predictive techniques are needed in order that the water-supply manager can effectively respond to the presence of contaminants in the karst aquifer.

In response to the widespread need for the protection of vulnerable ground-water supplies, Congress enacted the 1986 Amendments to the Safe Drinking Water Act. Prior to 1986, the Federal statutes available to the U.S. Environmental Protection Agency (EPA), although designed for more general purposes, provided substantial protection for ground water (U.S. Environmental Protection Agency, 1984, p. 23). These statutes are designed to protect ground water by focusing on controlling specific contaminants or sources of contamination. However, with the enactment of the 1986 Amendments to the Safe Drinking Water Act, there is for the first time a Federal statutory goal for the protection of ground water as reflected by the establishment of the Wellhead Protection Program. This goal represents a significant change in the roles and relations of Federal, state, and local governments with regard to ground-water protection.

The Wellhead Protection Program (Section 1428 of the Safe Drinking Water Act) is a state program designed to prevent contamination of public water-supply wells and well fields that may adversely affect human health. Although springs that supply public drinking water were not specifically mentioned in the statute, it has been interpreted by the EPA that the protection of public water-supply springs should be included in the program.

The Act requires states to develop programs to protect the wellhead protection area of all public water-supply systems from contaminants that may have any adverse effects on the health of humans. A wellhead protection area is defined by statute as the surface or subsurface areas surrounding wellfields through which contaminants are reasonably likely to move toward and reach such wells or wellfields.

The Act specifies that the following elements be incorporated into state programs:

A description of the duties and responsibilities of state and local agencies charged with the protection of public water-supplies:

Determination of wellhead protection areas for each public water-supply well.

Identification of all potential man-made sources within each wellhead protection area.

As appropriate, technical assistance; financial assistance; implementation of control measures; and education, training, and demonstration projects to protect the wellhead areas.

Contingency plans for alternative water supplies in case of contamination.

Siting considerations for all new wells.

Procedures for public participation.

States electing to develop a Wellhead Protection Program need to submit their program proposal to the EPA by June 1989 and the program needs to be implemented within two years of approval. The EPA has established a policy that states shall have considerable flexibility in carrying out the program.

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Guidance available from the EPA to states in developing their programs include "Guidance for Applicants for State Wellhead Protection Program Assistance Funds Under the Safe Drinking Water Act" (U.S. Environmental Protection Agency, 1987a) and "Guidelines for Delineation of Wellhead Protection Areas" (U.S. Environmental Protection Agency, 1987b).

Recognizing the occurrence of water supplies in karst aquifers of the southeastern United States, the U.S. Geological Survey in cooperation with Region IV of the Environmental Protection Agency, prepared this manual to assist Federal, State, and local agencies in ground-water management and protection in karst terranes to support the Wellhead Protection Program. The manual demonstrates the application of dye-tracing concepts and techniques for determining solute-transport characteristics of ground water in karst terranes and illustrates the development of predictive techniques for ground-water protection.

With the serious potential for ground-water contamination and the need to identify the areas most likely to drain directly to karst ground-water systems, numerous investigations by state and Federal agencies, university researchers, and environmental consulting firms have been conducted to better define the hydraulic nature of these systems. Some objectives of these investigations include, but are not limited to, the location and classification of sinkholes most susceptible to surface runoff; the identification of point-to-point hydrologic connections by dye traces between selected sinkholes, losing and sinking streams, and public water-supply springs and wells; and the definition of the relation between precipitation, storm-water drainageways, streams, sinkhole drainage, ground-water movement, and downgradient springs and wells.

Information gained from these studies has been helpful to local, state, and Federal water supply management and protection agencies and researchers in their efforts to develop aquifer and well-head protection plans. The results have been useful for developing land-use controls around sinkholes whose drainage has been traced to public water-supply springs or wells. Recent studies have demonstrated the use of predictive techniques for estimating solute transport in karst terranes.

1.2 Purpose and Scope

The purposes of this manual are to provide a review of the hydrogeology of karst terranes, summarize concepts and techniques for dye tracing, and describe and demonstrate the application of dye-trace data to determine solute-transport characteristics of ground-water in karst terranes. The manual was prepared in support of the Wellhead Protection Program pursuant to the 1986 Amendments to the Safe Drinking Water Act.

The dye-tracing procedures and the analysis and application of dye-trace data provided in this manual were used to determine ground-water flow characteristics in the Elizabethtown area, Kentucky (Mull, Smoot, and Liebermann, 1988). In general, these techniques may be used in other karst areas with similar hydrologic characteristics. The quantitative analyses of dye-recovery data and the development of prediction capabilities are most useful in areas where ground-water flow occurs primarily in conduits that drain to a spring or springs where discharge can be measured.

1.3 Acknowledgments

The authors are grateful to James F. Quinlan of the U.S. National Park Service; and Ronald J. Mikulak of the EPA, and Robert E. Faye and John K. Carmichael of the U.S. Geological Survey; each of whom performed a technical review of the manual. Their constructive criticism was beneficial to the technical content and accuracy of the manual.

The authors are also grateful to the City of Elizabethtown, which provided much of the dye-trace data used in this manual, for its cooperative support of a dye-trace investigation by the U.S. Geological Survey.

2. HYDROGEOLOGY OF KARST TERRANE

Karst is an internationally used word for terranes with characteristic hydrology and landforms. Most karst terranes are underlain by limestone or dolomite, but some are underlain by gypsum, halite, or other relatively soluble rocks in which the topography is chiefly formed by the removal of rock by dissolution. As a result of the rock solubility and other geological processes operating through time, karst terranes are characterized by unique topographic and subsurface features. These include sinkholes; karst windows; springs; caves; and losing, sinking, gaining, and underground streams, but in some terranes one or more of these features may be dominant. The hydrology of aquifers underlying karst terranes is markedly different from that of most granular or fractured-rock aquifers because of the abundance, size, and integration of solutionally enlarged openings in karst aquifers.

There are many different geologic settings and hydrologic conditions that influence the development and hydrology of karst terranes. For the purposes of this manual, many important aspects of the hydrogeology of karst terrane can be mentioned only briefly. A comprehensive guide to the hydrogeology of karst terranes and its literature has been published by White (1988). It and other references cited herein will direct the reader to more complete discussions of various aspects of the hydrogeology of karst terranes.

According to Davies and LeGrand (1972), about 15 percent of the conterminous United States, consists of limestone, gypsum, and other soluble rock at or near the land surface (fig. 1). Karst terranes are particularly well developed in the following areas: (1) Tertiary Coastal Plain of Georgia and Florida, (2) Paleozoic belt of the Appalachian Mountains stretching from Pennsylvania to Alabama, (3) nearly flat-lying Paleozoic rocks of Alabama, Tennessee, Kentucky, Ohio, Indiana, Illinois, Wisconsin, Minnesota, Arkansas and Missouri, (4) nearly flat-lying Cretaceous carbonate rocks in Texas, (5) nearly flat-lying Permian rocks of New Mexico, and (6) the Paleozoic belt of folded rocks in South Dakota, Wyoming, and Montana (LeGrand, Stringfield, and LaMoreaux, 1976). Much of the subsurface of the Coastal Plain in South Carolina and Alabama is a karst aquifer, but there is minimal surface expression of typical karst features. Most of the karst areas are underlain by carbonate rocks that have varying amounts of fractures. The fractures usually are enlarged by solution where they are in the zone of ground-water circulation. The enlargement of the fractures is controlled, in part, by geologic structure and lithology.

1.3 Acknowledgments

The authors are grateful to James F. Quinlan of the U.S. National Park Service; and Ronald J. Mikulak of the EPA, and Robert E. Faye and John K. Carmichael of the U.S. Geological Survey; each of whom performed a technical review of the manual. Their constructive criticism was beneficial to the technical content and accuracy of the manual.

The authors are also grateful to the City of Elizabethtown, which provided much of the dye-trace data used in this manual, for its cooperative support of a dye-trace investigation by the U.S. Geological Survey.

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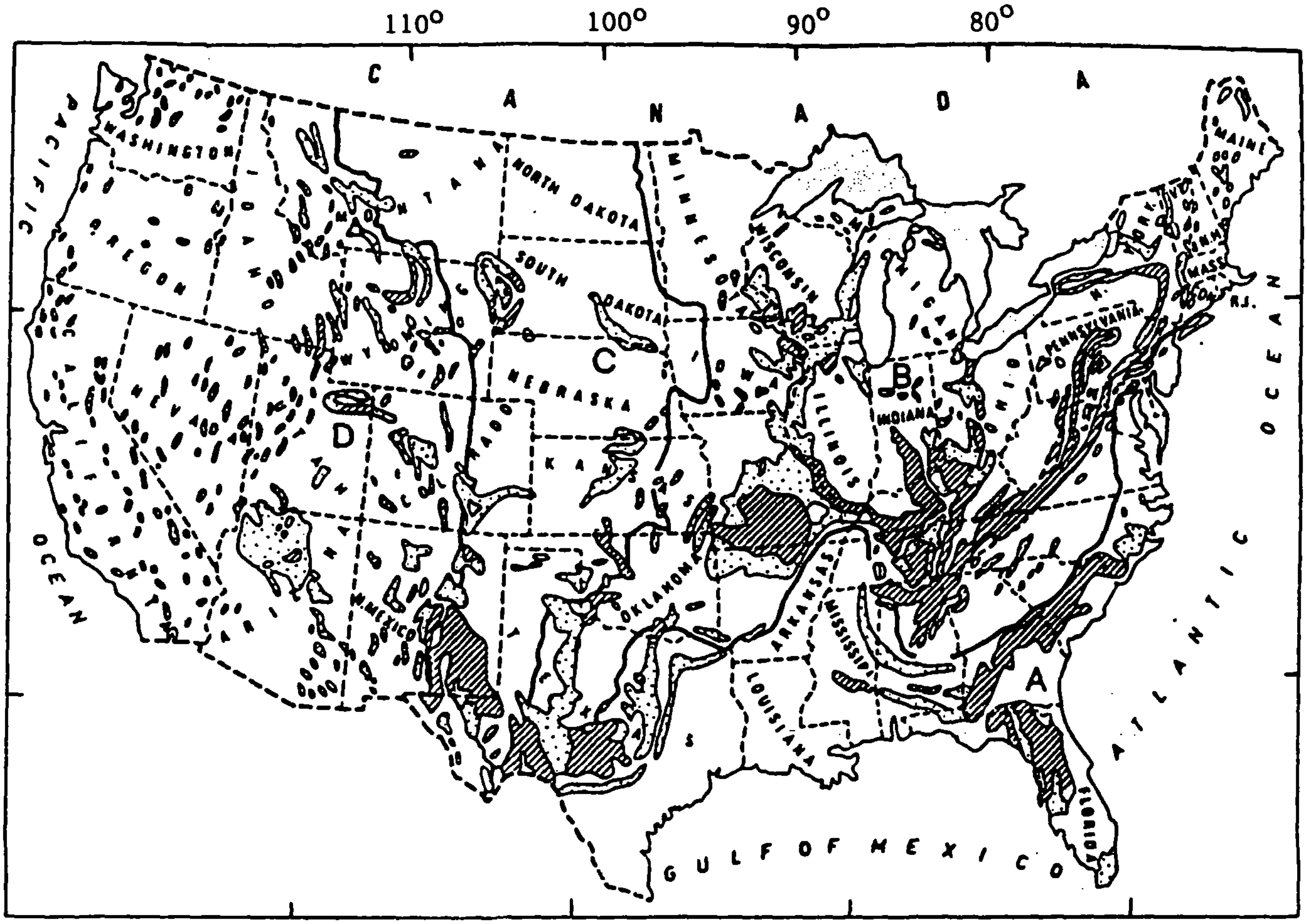

(from W.E. Davis, in Komatina, 1975, figure 7, p. 23)

EXPLANATION

A = Atlantic and Gulf Coastal Plain regions
B = East-central region
C = Great Plains region
D = Western mountain region

Karst areas

Carbonate and other soluble rock at or near the surface

0 200 400 600 MILES
0 200 400 600 KILOMETERS

Figure 1.--Distribution of karst areas in relation to carbonate and other soluble rock in the conterminous United States.

There are five key elements necessary for a ground-water basin to develop in carbonate rocks. It must have: (1) an area of intake or recharge, (2) a system of interconnected conduits that transmit water, (3) a discharge point, (4) rainfall, and (5) relief. If any one of these elements is missing, the rock mass is hydrologically inert and likely cannot function as a ground-water basin.

Ground-water recharge occurs as infiltration through unconsolidated material overlying bedrock or as direct inflow from sinking streams and open swallets. Infiltrated water moves vertically until it intercepts relatively horizontal conduits that have been enlarged by the solutional and erosive action of flowing water. Springs are the discharge points of the ground-water basin and usually are located at or near the regional base level or where insoluble rocks or structural barriers such as faults, impede the solutional development of conduits.

Adequate rainfall is necessary for the solution of limestone to take place. Karst development tends to be absent if precipitation is less than 10-12 inches per year. Maximum karstification occurs in regions of heavy precipitation and in regions with marked seasons of heavy precipitation and drought (Sweeting, 1973, p. 6).

The development of ground-water basins requires vertical and horizontal circulation of ground-water. Such development is enhanced if available relief places the soluble rock above the regional base level.

The presence of solutionally enlarged fractures presents unique problems for water managers in karst terrane because of the velocity of ground-water flow and the possibility that relatively little water-quality enhancement occurs while the water is in transit within the karst aquifers. Ground-water velocities in conduits may be as high as 7,500 feet per hour (ft/hr) where the potentiometric gradient is as steep as 1:4 (Ford, 1967). Under fairly typical ground-water gradients of 0.5 to 100 feet per mile (ft/mi), velocities range from 30 ft/hr during base flow to 1,300 ft/hr during flood flow within the same conduit (Quinlan and others, 1983, p.11). Under such conditions, pollutants can impact water quality more than 10 miles away in just a week during base flow (Vandike, 1982) and much sooner during flood flow.

Where fractures within a bedrock aquifer are well developed and ground-water flow is convergent to major springs via well developed conduits, the aquifer is considered to be mature. Mature carbonate aquifers are generally developed beneath mature karst terrane, having well-developed sinkholes that collect and drain surface runoff directly into the subsurface conduit system. Streams can also drain to the subsurface through swallets developed in the stream bed or disappear into a swallet at the end of a valley.

In maturely karstified terranes, springs in a given area generally have similar flow and water-quality characteristics. Spring discharge is normally flashy, responding rapidly to rainfall. Flow is turbulent and turbidity, discharge, and temperature are highly variable. Also, hardness is usually low but highly variable. Springs with these characteristics are the outlets for conduit-flow systems (Schuster and White, 1971, 1972) that usually drain a discrete ground-water basin. Flow in a conduit system is similar to flow in a

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If the aquifer is less mature, water moves through small bedrock openings that have undergone only limited solutional enlargement. Flow velocities are low and ground water may require months to travel a few tens of feet through the carbonate bedrock (Freidrich, 1981; Freidrich and Smart, 1981). Discharge from springs fed by slow-moving water in less mature karst is non-flashy, relatively uniform, and responds slowly to storms. Flow is usually laminar, turbidity is very low, and water temperature is very near the mean annual surface-water temperature. Springs with these characteristics are typical of ground-water outlets from diffuse-flow systems (Schuster and White, 1971, 1972).

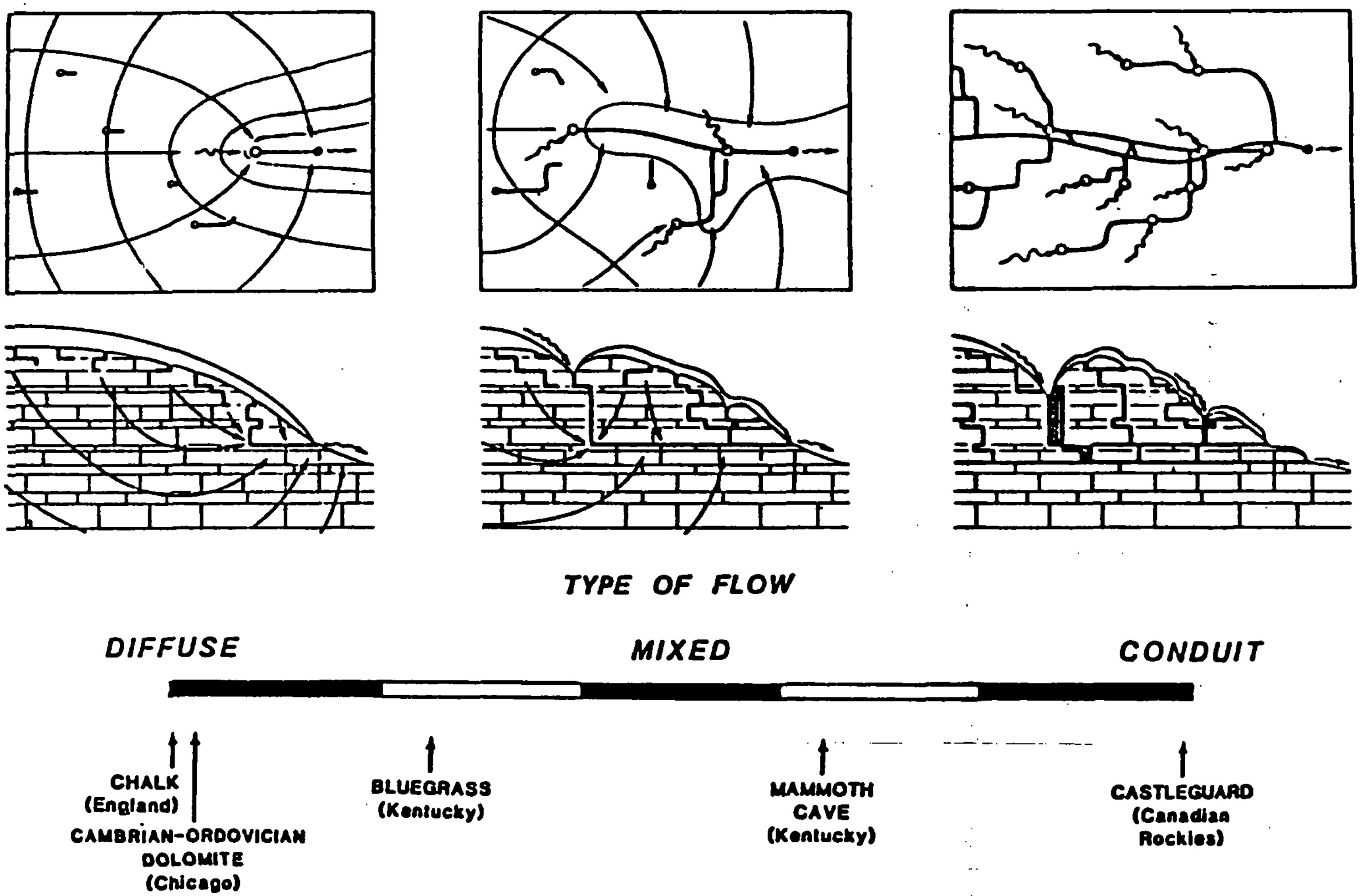
Quinlan and Ewers (1985) propose that the major portion of ground-water movement in a diffuse-flow (less mature karst) system is also through a tributary network of conduits. Only in the headwaters of a ground-water basin and adjacent to a conduit is flow actually diffuse. Their inspections in quarries and caves show that the smallest microscopic solutional enlargements of bedding planes and joints function as tributary conduits. They also propose that conduit and diffuse flow in carbonate aquifers are end members of a flow continuum (fig. 2). Although most carbonate aquifers are characterized by both types of flow, as discussed in detail by Atkinson (1977), generally, one type of flow predominates. Smart and Hobbs (1986) state that flow in massive carbonate aquifers tends to be either predominately diffuse or predominately conduit, depending on the degree of solutional development.

2.1 Karst Features

The most noticeable and direct evidence of karstification is the landforms that are unique to karst regions. Most karst landforms are the direct consequence of dissolution of soluble carbonate bedrock and are characteristic of areas having vertical and horizontal underground drainage. Although some karst landforms, such as sinkholes, may develop within a relatively thick zone of unconsolidated regolith overlying bedrock, it is the presence of solutionally enlarged openings in bedrock that ultimately controls the development of such features. Karst features include sinkholes; karst windows; springs; caves; and losing, gaining, sinking, and underground streams. These features are discussed in detail by White (1988), Jennings (1985), Milanovic (1981), and Sweeting (1973). The following discussion is limited to karst features that are most related to the ground-water system, primarily those that collect and discharge into, store and transmit, or discharge water from the ground-water system.

2.1.1 Sinkholes

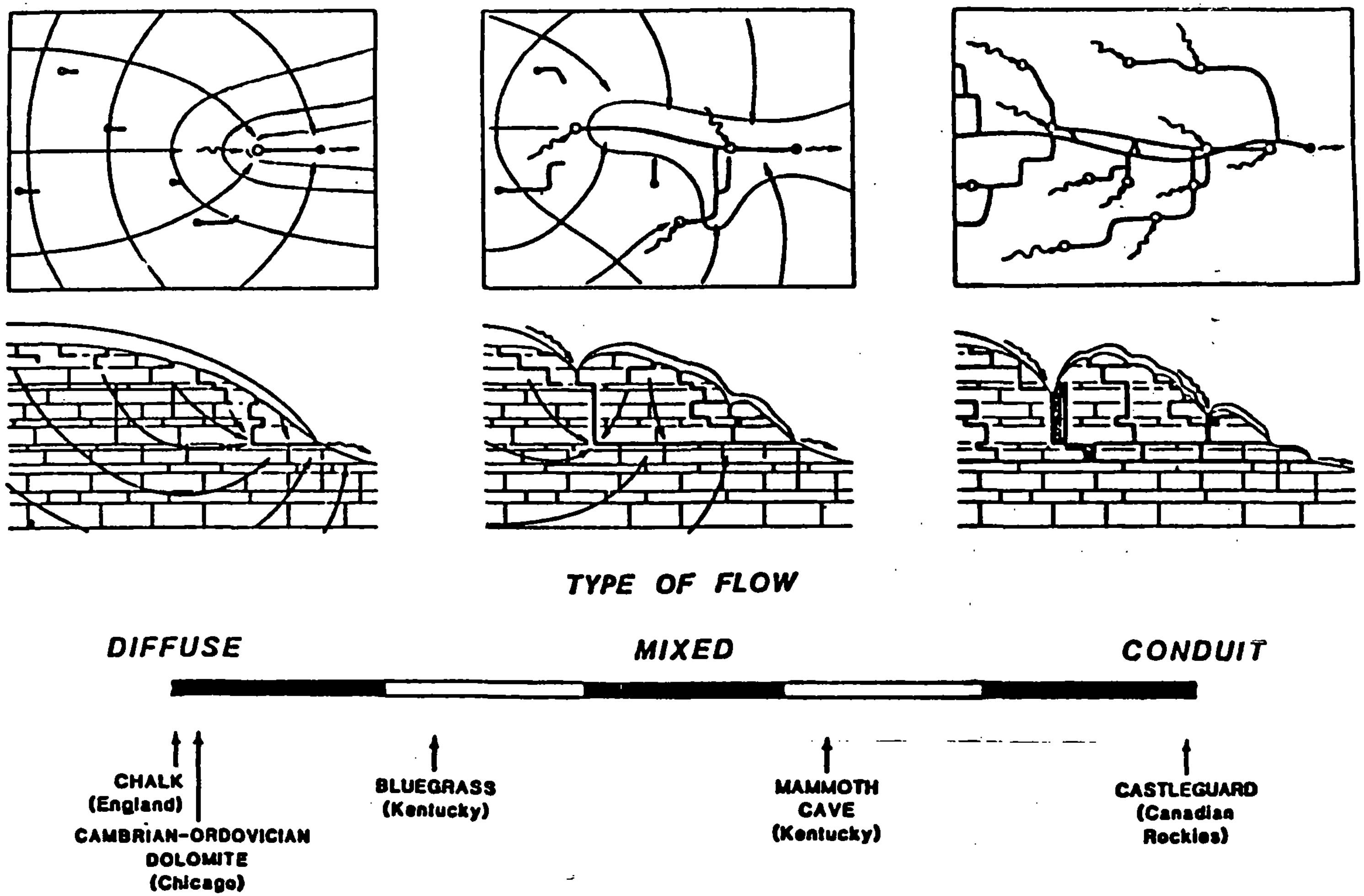
The term sinkhole has been used to identify a variety of topographic depressions resulting from a number of geologic and man-induced processes. In geologic research, the term doline is synonymous with sinkhole and has become standard in the literature. However, Beck (1984, p. IX), cautions against the use of the term sinkhole to describe depressions caused by mine collapse or other man-induced activities which are not caused by karst processes.



(adapted from Quinlan and Ewers, 1985, figures 4-5, p. 107-108)

The open circles indicate sinkholes that are water inputs. Blackened circles are springs. Wavy lines are surface streams. Heavy black lines are cave passages. Flow lines and equipotential lines are shown for diffuse flow and mixed flow, but the concept of such lines is not applicable in a purely conduit system.

Figure 2.--Diffuse, mixed, and conduit flow in a hypothetical ground water basin, showing the sequence of its evolution.



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Therefore, as used in this manual, the term sinkhole refers to an area of localized land surface subsidence, or collapse, due to karst processes which result in closed depressions (Monroe, 1970 and Sweeting, 1973, p. 45).

Sinkholes are depressions that can provide a direct path for surface runoff to drain to the subsurface. They can occur singly or in groups in close proximity to each other. In size, diameter is usually greater than depth, and average sinkholes range from a few feet to hundreds of feet in depth and to several thousand feet in diameter (Sweeting, 1973, p. 44). Sinkholes are generally circular or oval in plan view but have a wide variety of forms such as dish or bowl shaped, conical, and cylindrical (Jennings, 1985, p. 106). Increasing size is usually accompanied by increasing complexity of form. Sinkholes frequently develop preferentially along joints in the underlying bedrock. This often results in sinkholes which have a distinct long dimension which corresponds with local joint patterns.

The number of sinkholes generally depends on the nature of the land surface and the depth of karstification. In general, plains tend to have a large number of sinkholes of small size, and hilly terranes tend to have fewer sinkholes but of larger size. On steep slopes, sinkholes are uncommon, but if found they are likely the result of collapse of cave roofs rather than gradual subsidence of surficial materials (Milanovic, 1981, p. 60).

Several natural processes contribute to the formation of sinkholes including solution, cave-roof collapse, and subsidence. Sinkholes are generally formed by the collapse or migration of surface material into the subsurface that results in the typical funnel-shaped depressions. In general, there are two types of collapse that form sinkholes: (1) slumping of surface material (regolith collapse) into solutionally enlarged openings in limestone bedrock and (2) collapse of carbonate (limestone) cave roofs. Sinkholes caused by the collapse of cave roofs may be either shallow or deep-seated and may develop suddenly when the cave roof can no longer support itself above the underlying cave passage. Although dramatic and at times damaging, this process is considered by some investigators to be the least common cause of collapse sinkholes.

Sinkholes can also form as a result of man's activities which tend to accelerate natural processes. Such induced sinkholes are caused primarily by ground-water withdrawals and diversion or impoundment of surface water which accelerates the downward migration of unconsolidated deposits into solutionally enlarged openings in bedrock (Newton, 1987). Induced sinkholes may provide convenient sites for dye injection and monitoring similar to natural sinkholes. However, care must be used because the area around these sites can be much less stable than in the vicinity of natural sinkholes.

There are numerous systems for the classification of sinkholes based on characteristics as varied as their processes of formation, size and orientation, and relation to surface runoff and the water table. The classification system proposed for use in this manual is based on the relative ability of the sinkhole to transmit water to the subsurface. This system emphasizes the interrelation between sinkholes and the ground-water system and especially the potential for sinkholes to funnel surface runoff directly into the subsurface. The system was used by Mull, Smoot, and Liebermann (1988) to identify those sinkholes with the greatest potential for contaminating the ground water in the Elizabethtown area, Kentucky. The criteria for sinkhole classification are based on the material in which the sinkhole is developed (sedimentary rock) and the presence or absence of drain holes (swallets). These criteria yield four types of sinkholes:

(1) sinkholes developed in unconsolidated material overlying bedrock with no bedrock exposed in the depression, but with well developed, open swallets that empties into bedrock,

(2) sinkholes that have bedrock exposed in the depression and a well developed swallet that empties into bedrock,

(3) sinkholes or depressions in which the bottom is covered or plugged with sediment and in which bedrock is not exposed, and

(4) sinkholes in which bedrock is exposed but the bottom is covered or plugged with sediment.

Sinkholes of types 1 and 2, having a well-developed, open drain or swallet, are thought to have the greatest potential for polluting ground water because the open drain is usually connected to subsurface openings that lead directly to the ground-water system. Thus, there is no potential for enhancement of water quality by processes such as filtration, as may be the case if water percolates through soil or other unconsolidated material at the bottom of types 3 and 4 sinkholes that do not have open swallets. Because of the open drains, types 1 and 2 sinkholes offer the most direct method for injecting tracers (dye) into the ground-water flow system because the tracers can be added to water draining directly to the subsurface through the open swallet.

Although types 3 and 4 sinkholes may be hydraulically connected to the aquifer system, the potential for pollution is generally less than from sinkholes with open drains because the percolation of water through sediments may provide some enhancement of quality before the water reaches the aquifer. Types 3 and 4 sinkholes can also be used as dye injection points during tracer tests, but the quantity and type of dye used must reflect the fact that the dye must first percolate through the soil plug before reaching the subsurface flow system. Also, dye traveltimes from types 3 and 4 sinkholes are difficult to predict because of the time required for water and dye to percolate through the soil plug.

The nature of the swallet and the hydraulic characteristics of the underlying aquifer will, in part, control the rate and quantity of water draining from the sinkhole. Ponding or sinkhole flooding can occur in types 1 and 2 sinkholes if runoff exceeds the drainage capacity of the swallet or if the subsurface system of conduits which receives sinkhole drainage is blocked. Drainage from sinkholes is also controlled by the nature of sediment and debris washed into the swallet. Heavy sediment loads, such as are common from freshly disturbed construction or cultivated sites, coupled with large debris, can partially obstruct or plug the swallet resulting in the ponding of water in the sinkhole. Soil and debris plugs can be temporary and be flushed open with subsequent heavy runoff. Mull and Lyverse (1984, p. 17) reported several instances following periods of rapid runoff in which water collected in and overflowed sinkholes because the drain was partially plugged. In some cases, ground water in the Elizabethtown area, Kentucky. The criteria for sinkhole classification are based on the material in which the sinkhole is developed (sedimentary rock) and the presence or absence of drain holes (swallets). These criteria yield four types of sinkholes:

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Because virtually all surface runoff that is collected by sinkholes is eventually funneled directly into the ground-water system,. drainage through sinkholes can seriously impact water supplies developed from underlying carbonate aquifers. Thus, it is imperative that water managers identify those sinkholes and sinkhole areas that recharge a particular karst water-supply spring or well in order to develop adequate ground-water protection procedures. Such procedures can be preventive, such as the application of land-use restrictions around selected sinkholes, or reactive, such as the determination of traveltimes and other aquifer flow characteristics developed from quantitative dye tracing.

Sinkholes are often the most ubiquitous evidence of karstification. Although some authors consider the absence of sinkholes sufficient evidence to classify an area as non-karst, Dalgleish and Alexander (1984) point out that in some areas of the Midwest more than 60 percent of the existing sinkholes are not shown on 7 1/2-minute (1:24,000) topographic maps. Also, Quinlan and Ewers (1985) state that karst cannot be defined solely in terms of the presence or absence of sinkholes. As a generalization, almost any terrane underlain by near-surface carbonate rocks has some degree of karst and can, therefore, exhibit water supply and protection problems that are characteristic of classic karst terranes.

2.1.2 Karst Windows

A karst window is a landform that has features of both springs and sinkholes. It is a depression with a stream flowing across its floor: it may be an unroofed part of a cave. Thrailkill (1985, p. 39) adds the criteria that karst windows are deep sinkholes in which major subsurface flow surfaces and that the streamflow is near the level of major subsurface flow.

Most karst-window streams issue as a spring at one end of the sinkhole, flow across its floor, and sink into the subsurface through a swallet. The length of the surface flow varies from what may appear to be a pool in the bottom of a sinkhole to a stream several hundred feet long (Thrailkill, 1985, p. 39). As with a sinkhole that drains to the subsurface, the karst window may flood and overflow its depression if the openings draining to the subsurface become blocked or if the subsurface conduits receiving that drainage are filled. Karst windows are hydrologically significant because the exposed streams provide a direct path to the subsurface for any contaminant deposited in or near the sinkhole. Also, they serve as convenient ground-water sampling and monitoring points.

REFERENCE 30

CHEVRON ORLANDO SITE

REMOVAL ACTION REPORT
DECEMBER 1992

Brown and Caldwell
Consultants

43 Perimeter Center East
Suite 500
Atlanta
Georgia 30346-1905
(404) 394-2997
FAX (404) 396-9495

December 17, 1992

Mr. Larry Brannen
On-Scene Coordinator
United States Environmental Protection Agency
Region IV
345 Courtland Street N.E.
Atlanta, Georgia 30365

22/6434-01/01
03/05

Subject: Removal Action Report
Chevron Orlando Site

Dear Mr. Brannen:

Brown and Caldwell has completed the Removal Action Report for the Chevron Orlando Site in compliance with the Administrative Order on Consent. Enclosed please find three copies of the Removal Action Report. We are sending you only one copy of the appendix (the appendix consists of six (6) volumes) under separate cover from our Orlando office.

Completion of the report fulfills the obligations of the Consent Order. It is our understanding that upon reviewing the report, you will issue a letter stating that Chevron has completed all of the activities required in the consent order. Please contact me if you have any questions or comments regarding the report.

Very truly yours,

BROWN AND CALDWELL

Linda Henry for

Michael P. Smith, P.E.
Project Engineer

MPS:dlt
6434\RAR\6434LT1.MPS
Enclosures

cc: Jeff Wyatt, Chevron Chemical Company
Linda Henry, Brown and Caldwell
Peter Robinson, Brown and Caldwell

CHAPTER 5

GROUNDWATER INVESTIGATION

This chapter presents information on the previous investigations, topography, climate, geology, hydrology/hydrogeology and the nature and extent of affected groundwater. One additional focus of this chapter is to discuss potential changes due to the removal action. The data on hydrogeology and groundwater were collected prior to the removal action. There has been no information collected since the removal action.

In summary, the key findings include:

- the site is relatively flat with 30 feet of porous sand and natural fill material above a non-porous, low permeability clay layer. Infiltration of surface water is rapid into a shallow non-potable aquifer that is present above the clay layer.

- the shallow groundwater is found at about 6 feet below ground level and flows in a north-easterly direction at an estimated rate of 12 feet per year. It will take approximately 8 years for groundwater to travel 100 feet across the site.

- groundwater now has to flow around the sheet piling in the center of the site which will create a local change in direction and elevation. Groundwater flow will be less affected by the sheet piling along the southern edge of the site because the sheet piling does not extend to the clay layer.

- volatile organic chemicals (xylene, toluene, ethyl benzene and benzene) are the most frequently identified compounds in groundwater with lindane (gamma-BHC) and its sister pesticides ranking as the second most commonly identified compounds.

- prior to the removal, the extent of affected groundwater was not clearly defined. Also, upgradient water quality is not defined because of the absence of upgradient offsite wells along the southern boundary.

- the removal action resulted in an average of 91 percent reduction in the concentration of chemicals in soil which are a concern in groundwater.

SUMMARY OF PREVIOUS INVESTIGATIONS

The Chevron Orlando site groundwater conditions have been investigated previously and the results documented in three previous reports. Dames and Moore, Jammal & Associates, and NUS

Corporation performed limited groundwater investigations prior to 1990, (see references). In 1981 and 1982, Dames and Moore sampled soil and groundwater and reported the presence of lindane and chlordane in soil and lindane and metals in groundwater. Dames and Moore concluded that contaminants were not migrating offsite. In 1987, Jammal and Associates analyzed groundwater for synthetic and volatile compounds but not pesticides. Benzene, xylene and other volatile compounds were identified above Florida maximum contaminant levels (MCL's). In May 1989, NUS Corporation conducted a site screening under CERCLA and reported the presence of pesticides, volatiles and metals in soil and groundwater. The most recent groundwater investigations are two studies conducted by Brown and Caldwell, a Contamination Assessment conducted in September 1990 and studies conducted June to October 1991, prior to and during the removal action.

Contamination Assessment Report (CAR) Groundwater Investigation

The CAR (BC, 1991) groundwater investigation involved installation and sampling of fourteen monitoring wells. Nine wells were installed to 17 feet below land surface (bls), two wells were installed to 22 feet bls, and three wells were installed to 33 feet bls. The wells were located within the property boundaries on three corners, in the area of the rinsate pond, and other areas of suspected contamination. Two sets of shallow/deep well clusters were included to assess potential vertical migration of the contaminants.

Groundwater data collected during the CAR investigation included water table elevations, hydraulic conductivity, and laboratory analysis for volatile and semi-volatile organic compounds, organochlorine pesticides, organophosphate pesticides, chlorinated herbicides, arsenic, chromium, and zinc.

Removal Action Plan Groundwater Investigation

Additional groundwater investigations were conducted as part of the removal action. Eighteen groundwater samples were obtained using a Hydropunch® and four permanent stainless steel monitoring well clusters were installed based on Hydropunch® data. One well cluster was installed onsite and three well clusters were installed on property downgradient and adjacent to the site. The well clusters were constructed of shallow/deep pairs installed at 15 and 30 feet bls. Groundwater samples were obtained from the 14 existing and the eight newly installed monitoring wells and analyzed for volatile organics, organochlorine pesticides, organophosphate pesticides, chromium, and arsenic.

TOPOGRAPHY AND CLIMATE

Orlando is located in the central or mid-peninsular zone in Florida (White, 1970). The central zone has gently rolling hills separated by broad valleys that roughly parallel the present coastline.

The site is located in an area known as the Osceola Plain, a broad valley bounded by the Lake Wales Ridge on the east and the Mt. Dora and Orlando Ridges on the west. See Figure 5-1. The site is at an elevation of approximately 100 feet above mean sea level. Within a 1 mile radius of the site elevations remain at 100 feet declining to 90 feet at Lake Fairview.

See Figure 5-1

Prior to the removal action, there was a 6-foot difference in surveyed elevations at the site ranging from 96 feet in the swale at the northwest corner of the property to 102 feet at the southeast corner.

Excavation activities have left the site slightly more level. Post excavation elevations range from 98 feet at the northwest corner to 101 feet at the southeast corner of the property.

The climate of the Orlando area is sub-tropical with two pronounced seasons, winter and summer. The average annual temperature is 72° F with the average high of 82° F occurring in August, and the average low of 61° F occurring in January. Average annual rainfall is between 50 and 55 inches. Most of the yearly rain occurs in the summer months (May to September) and afternoon thunderstorms occur almost daily during this season.

GEOLOGY

The geology of the site and the region is characterized by a shallow (30 feet) layer of loose, porous sand, thick (0-200 feet) layer of clay, sand and phosphatic limestone (Hawthorn Formation) and underlying deposits of limestone.

General Description

Regionally, the geology of Florida has resulted from rising and falling of sea level associated with glaciation of the North American continent. Florida received deposits of sand and limestone at times when the land was covered by shallow seas. As waters receded, rivers and streams became the main sources of deposition, bringing land-derived sand and clays to lie over the marine carbonates. Swamps and lakes contributed deposits of peat and clay.

In east-central Florida, the sedimentary deposits reach a thickness of approximately 6,500 feet and overlie a basement of granite and other crystalline rocks.

On a more local scale, the surface deposits are predominantly sand and clayey sand that is loose and unconsolidated. See Figure 5-2a. Underneath the 30 feet of loose sand is a clay layer called the Hawthorn Formation. The Hawthorn Formation is 0-200 feet thick and consists of grey-green clay, clayey sand and silt, sand and limestone. The limestones are more prevalent in the lower portion of the formation.

See Figures 5-2a and 5-2b

The clays and sands are more prevalent in the upper portion of the formation. See Figure 5-2b.

Beneath the Hawthorn Formation are multiple layers of deposited limestones of various thicknesses, characteristics and age probably exceeding 1,300 feet in thickness. The exact thickness of the limestone layers is unknown at the site.

Site-Specific Information

The surficial layer at the site consists of a dark grey layer of top soil that is sandy with organic matter throughout. The top layer varies in thickness but was generally 3 feet thick. Below the top soil or fill material, sand, clayey sand and silty sand occur. Across the site, the silty sand appears at approximately 10 feet in depth and varies in thickness, usually approximately 4 to 5 feet. The clayey sand occurs in lenses at various depths. The variations in clay and silt content are gradual and not distinct. The inclusion of silt and clay in the sand deposits serves to reduce porosity which in turn may restrict groundwater flow.

The sand ranges from near white to very dark brown with no discernable color pattern except in the excavation area at approximately 10 feet deep where a distinct layer of brown sand overlies white sand. The sand grains throughout the site are fine to very fine grained, well sorted and moderately well rounded.

The surface soil is highly porous and receptive to infiltrating rainwater. The measured porosities of the sand layers at 6 to 8 feet below grade was 57 to 60 percent. Dry and wet densities for the same sands were 97.6 to 102.0 pcf and 119.5 to 126.2 pcf, which is generally high for sand but this may indicate a high content of heavy minerals in the sand.

Beneath the loose sand deposits, a stiff, impermeable, grey clay layer was encountered. This clay layer is considered to be the top of the Hawthorn Formation which serves as the confining unit between the surficial aquifer and the Floridan Aquifer.

The clay layer is thought to be continuous beneath the site and occurs at depths ranging from 27 feet (at MW-M) to 42 feet (at Dames and Moore soil boring #9). The clay layer was encountered in 18 of 19 wells or borings drilled to depths of 27 to 42 feet. The base of the clay layer was not encountered as none of the wells or soil borings were designed to fully penetrate the clay layer. Figure 5-3 is a north/south geologic cross section of the site derived from monitoring well boring logs. Figure 5-4 is an east/west cross section and Figure 5-4a shows the location of each cross section.

See Figures 5-3, 5-4 and 5-4a

In addition to these characteristics, a "hardpan" or hard and compacted layer was present in the area of the railspur along the south property line. The hardpan probably resulted from years of vibration of the soil underneath the railspur. The hardpan consisted of dark brown fine grained sand and was encountered at a depth of approximately 6 feet and was 6 inches to 1 foot thick. A distinct cementing agent was not apparent. The layer extended from the southeast corner of the property westward to about grid line E300. Drilling and excavation equipment could not penetrate the hardpan and these activities stopped at the depth hardpan was encountered.

Current Conditions

The removal action has resulted in several local changes to the geology of the shallow soil at the site. The top soil of higher organic content has been replaced over 50 percent of the site and 17 percent of the deeper soil has also been replaced. The fill material of clean sand is expected to be equally or more porous than the native soil.

Sheet piling, present in the center and southern edge of the site, changes the natural geologic conditions in areas of the site. In the center of the site, the sheet piling extends 30 feet to the clay layer. The sheet piling along the southern edge extends 12 feet into the 30-foot sand layer.

HYDROLOGY/HYDROGEOLOGY

This section presents information on surface water, drainage, groundwater, and regional and local water use.

There is no standing surface water on the site and little surface runoff due to high rates of infiltration. Groundwater is present in two aquifers or water-bearing zones beneath the site: a non-artesian aquifer in the shallow sand layer that is not used for drinking water and the artesian Floridan Aquifer below the Hawthorn Formation that is used extensively for drinking water.

Site Drainage and Surface Water

The surface soil at the site is porous and rainwater tends to infiltrate rapidly. In heavy rainfalls prior to the removal action, site drainage was to the north-west into a 3-foot by 10-foot swale along the north property line. Based on observations during pre-removal investigations, stormwater infiltrated or evaporated, but little runoff occurred, during the majority of storm events. On the eastern paved portion of the site, drainage was into the storm drain system along Orange Blossom Trail.

Drainage on the south property boundary was along the railspur towards the west. In heavy rainfall events, stormwater traveled along the railspur and collected in a low area on the property adjacent to the west property line (North Brothers Insulation property). A stormwater retention pond is located on the western side of North Brothers property. It is possible that stormwater drainage from the site may enter this pond during extreme rainfall events.

As part of the site restoration activities after soil removal, grading was performed that is designed to direct surface drainage towards the northwest property corner in order to reflect pre-excavation surface slopes. Since all impermeable surfaces were removed, infiltration should be rapid with very little run-off occurring. Since site restoration has been completed, no storm events have been observed at the site. Observations made approximately two hours after an average rainfall (total inches unknown) noted that no standing water was present.

See Figure 5-5

Lake Fairview and Lake Silver are the dominant surface water features within 1 mile of the site; however, surface water runoff from the site could not reach either of these lakes. These lakes are used mainly for recreational purposes although other lakes in Orange County are also used for irrigation.

Lake Fairview has an average depth of 27 feet and does intersect the shallow water table aquifer in the area.

Aquifers

Groundwater occurs in an unconfined shallow aquifer in the shallow sand layer and in the prolific Floridan Aquifer. In other areas of the region, there are also intermittent aquifers in the Hawthorn Formation. These aquifers are intermittent and isolated. A secondary artesian aquifer is not present at the site.

The shallow aquifer at the site is part of an extensive system that extends throughout southeastern Florida and parts of South Carolina and Georgia. The aquifer is composed of quartz sand with varying amounts of clay, hardpan and shell.

See Figure 5-6

The shallow aquifer has been the focus of these investigations. A total of 22 monitoring wells were advanced to depths of 15, 17, 22, 30 and 33 feet to monitor the upper and lower portions of the surficial aquifer at the site. The upper and lower portions are areas of the same aquifer and there is no continuous confining layer between these intervals.

At the site in October 1991, groundwater was encountered at depths ranging from 5 feet bls to as deep as 12 feet bls. During these investigations, the water table occupied approximately the lower 24 feet of the 30 feet of loose sand above the confining layer.

This is consistent with regional information that this water table surface is 0 to 20 feet bls with a thickness that is generally less than 50 feet although it may reach up to 400 feet in parts of Florida.

At 30 feet, the clay layer that is considered to be the upper surface of the Hawthorn Formation was encountered. This layer serves as a confining layer which separates the shallow aquifer from a deep artesian aquifer.

The deep artesian aquifer is part of the Floridan Aquifer system that underlies all of Florida and parts of Alabama, Georgia and South Carolina. The Floridan Aquifer is comprised of multiple layers of limestone underlying the Hawthorn Formation. See Figure 5-7. The Floridan Aquifer is estimated to be up to 2,000 feet thick in the Orange County area. The potentiometric surface of the Floridan Aquifer beneath the site is between 30 and 40 feet bls. This indicates that vertical groundwater flow potential is upward into the Hawthorn Formation.

See Figure 5-7

Recharge Zones

Recharge to the shallow water table aquifer at the site is mainly through infiltration of rainfall. Within 1 mile of the site artificial recharge may occur by infiltration of irrigation water, septic tank discharge and discharge from flowing wells. Discharge from the non-artesian aquifer is by seepage into surface water bodies, leakage to underlying aquifers, pumpage and trees.

Recharge to the Floridan Aquifer in Orange County is from infiltration of rain through the relatively semi-permeable confining beds and through the drainage wells. Discharge from the Floridan Aquifer is by outflow into surrounding counties, upward leakage, pumpage and spring outflow. There are no known discharge areas on or near the site.

Water Levels and Groundwater Flow Direction

Groundwater flows in a north-east direction across the site. This was determined from measured depths to groundwater and surveyed elevation data for each well. See Figure 5-8 and Table 5-1. The groundwater gradient for the surficial zone is .006 ft/ft (between MW-D and MW-P) toward the northeast corner of the site and thus flow direction is towards the northeast corner of the site.

See Figure 5-8 and Table 5-1

Water table maps were completed for all wells less than 22 feet deep and for those greater than 22 feet deep. Groundwater elevations and gradient at shallow/deep well clusters were compared to determine if there were two zones within the surficial aquifer unit at the site. Water table differences between the two intervals monitored (7-17 feet and 23-33 feet) ranged from .04 feet at MW-1S/1D to .28 feet at MW-3S/3D. The groundwater gradient between MW-1S and 2S over a distance of 283 feet was .007. The gradient between MW-1D and 2D was also .007. These small differences in water elevation and similar gradients indicates that there is little or no apparent hydraulic separation between the upper and lower intervals.

Aquifer Testing

In order to evaluate aquifer characteristics for the shallow formation at the site, in-situ permeability test, or "slug tests", were performed. Tests were performed during the CAR investigation in October 1990 on monitor wells O, K and L and were also performed in the Remedial Action Report investigation in October 1991 on Monitor wells MW-1S, 1D, 2S, 2D and 4S and 4D. The October 1990 tests were performed manually and the October 1991 tests were performed using an In-Situ brand data logger. The data logger consists of a pressure transducer which records changes in water pressure due to changing head over the transducer. The transducer was placed in the bottom of the well, a slug of water was removed using a bailer of known volume, and the transducer recorded the rate of rise of water level in feet in the well.

Graphic plots of slug test data (time vs. recovery in feet) were generated (See appendix F). Values of hydraulic conductivity (k) were determined using the Bouwer and Rice method (1976) as follows:

$$k = \left(\frac{r_c^2 \ln (R_e/r_w)}{2L_e}\right)\left(\frac{1}{t}\right)\left(\ln\frac{Y_0}{Y_t}\right)$$

where R_e = effective radial distance over which the head difference Y is dissipated,

r_w = radial distance between well center and undisturbed aquifer,

L_e = height of screened section of the well through which groundwater enters,

Y_0 = water level at time zero,

Y_t = water level at time t, and

t = time since Y_0.

Values for hydraulic conductivity ranged from 1.82 ft/day to 6.74 ft/day. See Table 5-2.

See Table 5-2

Based on measured values for hydraulic conductivity, average linear flow velocity and discharge volume can be estimated. Average linear flow velocity is a function of hydraulic conductivity (k), effective porosity of the soil (η_e) and the hydraulic (groundwater) gradient (I) or

$$v = kI / \eta_e.$$

The average hydraulic conductivity at the site is 3.78 ft/day. The hydraulic gradient across the site is .006 foot/foot and the measured porosity ranged from 57 to 60 percent. Thus, the calculated average linear flow velocity across the site is approximately .038 ft/day (13.5 ft/year). Since the measured porosities appear to be high for a fine-grained sand, average porosities, based on a literature search, were also used to calculate the flow velocity. Average low (25 percent) and high (50 percent) values for porosity of fine-grained sands were chosen and yield flow velocities of .09 ft/day (32.5 ft/year) and .045 ft/day (16.4 ft/year). Based on the above flow velocities, it is expected that groundwater would move 100 feet across the site in 3.0 to 7.4 years, assuming that consistent conditions prevail.

Discharge (Q) is based on flow velocity (v) and the cross sectional area of the aquifer (A = width x vertical thickness) or

$$Q = vA.$$

Based on the thickness of the surficial aquifer (approximately 24 feet from top of water table to the top of the confining layer) and an arbitrary width of 100 feet, the discharge for that 100 feet is 84 ft^3/day or 629 gallons per day. Transmissivity, or the capacity of an aquifer to transmit water, is a function of a formation's hydraulic conductivity and its thickness, or $T = kb$. For the shallow aquifer at the site, $T = 3.78$ ft/day x 2.4 ft = 91 ft^2/day.

The shallow aquifer is less permeable and contains less water than the Floridan Aquifer. The permeability of the Floridan Aquifer is due to solution of limestone and dolomite by circulating groundwater. Transmissivity of the Floridan Aquifer may be 50,000 ft^2/day or more.

Area Water Supply and Drainage Wells

Groundwater in Orange County accounts for all water used for municipal, domestic and industrial supplies and half of the agricultural supplies. The largest use of groundwater is for utilities. Surface water is used for irrigation, for cooling electric generators and for recreation.

A well survey was completed by Dames and Moore in 1982 utilizing United States Geological Survey (USGS) data on industrial and residential wells in the area and a field survey. Within a 3-mile radius of the site, 15 industrial wells and 8 residential wells were identified. These wells ranged in depth from 120 to 1,500 feet and obtain water from the Floridan Aquifer.

The Floridan Aquifer system is generally 10 times more permeable than its upper and lower confining units. The system can be divided into the Upper and Lower Floridan Aquifers which are separated by a less permeable confining or semi-confining unit. Water quality varies between the upper and lower aquifer units with the Lower Floridan containing saltwater in some places. In the Orange County area the upper producing zone extends from approximately 150 to 600 feet. The lower zone extends from approximately 1,100 to 1,500 feet. Most municipal water supplies are developed in the lower zone while the upper zone is utilized for excess surface water disposal through drainage wells.

Drainage wells were constructed to drain surface water directly into the Floridan Aquifer. More than 300 drainage wells were drilled between 1906 and 1961 in the upland area of the county, especially in Orlando. A drainage well at the northwest corner of Lake Fairview has been capped. Florida Department of Transportation inventories and maintains drainage wells on state right-of-ways. Their records indicate a drainage well approximately 1 mile west of the intersection of Orange Blossom Trail and Silver Star Road on Silver Star Road.

Current Conditions in Hydrogeology

The removal action resulted in changes to the composition of the subsurface and groundwater flow by the presence of sheet piling in two areas. A conceptual flow diagram was prepared to show the potential impacts of these changes on groundwater flow direction. See Figure 5-9.

See Figure 5-9

The sheet piling around the central excavation is keyed into the confining layer and will obstruct the flow of groundwater. As shown in Figure 5-9, groundwater will flow around the sheet piling. Little or no direct circulation with water inside the piling is expected to occur; however, slow leakage is expected.

Over time, equilibrium between water levels inside and outside are expected to occur. Water inside the sheet piling can percolate through the clay layer or breaks in the sheet piling. At this time, predicting changes in water table elevation would be speculative and will depend on localized differences in relative infiltration rates and surface drainage. Short term differences in water table elevations could occur. In wet periods, water could temporarily mound inside the central sheet piling while in dry periods, water levels inside the sheet piling could be lower than those outside.

The sheet piling along the southern edge of the site extends approximately 6 feet into the groundwater table and is not considered to represent a significant obstruction to groundwater flow. The upper 6 feet of groundwater will divert to flow either around or under the sheet piling. The amount of diversion will depend on the depth of the water table. Also, the depth of the water table will fluctuate seasonally and the amount of water diverted will vary.

At this time, there are twelve remaining monitoring wells. Ten wells were located inside excavation areas and were abandoned during the removal. Figure 5-9 also shows the location of the remaining monitoring wells at the site.

NATURE AND EXTENT OF CHEMICALS IN GROUNDWATER

This section discusses the nature and extent of affected groundwater. There are three sets of groundwater samples, two from monitoring wells for September 1990 and October 1991, and one set of Hydropunch® samples in October 1991. The analytical data are presented on Tables 5-3, 5-4, and 5-5. Table 5-6 presents a summary of the data and Figures 5-10 and 5-11 show distribution. Table 5-7 lists the physical and chemical properties of the compounds identified in the groundwater.

See Figures 5-10 and 5-11

See Tables 5-3, 5-4, 5-5, 5-6 and 5-7

Monitoring Well Samples

An evaluation of the monitoring well samples shows that the most prevalent chemicals are volatile organic chemicals and lindane (gamma-BHC and its sister compounds).

Inspection of Tables 5-6 and 5-7 shows that the most frequently identified chemicals are xylene and ethyl benzene with 68 and 65 percent frequency of detection, respectively. These chemicals, along with benzene and toluene, identified at lower levels of 29 and 26 percent frequency, are totaled as BTEX for presentation on Figures 5-10 and 5-11.

The highest BTEX concentrations were identified in MW-E, off the western edge of the building, and MW-L, near the center of the excavation area, in both sampling events. MW-E is in the area that was excavated for total petroleum hydrocarbons. Information on past activities at the site indicates that this area was used for vehicle engine repair. The BTEX may have resulted from spills in this area.

The BTEX concentrations throughout the rest of the site are fairly consistent with MW-F and MW-N, off the corners of the building, are somewhat lower.

In the probable upgradient locations, MW-D and MW-A in the southwest and southeast corners of the site, respectively, BTEX compounds were not identified in either sampling event. However, there are data gaps in upgradient information because there are no upgradient wells along the western edge of the site and in the middle of the southern edge of the site. BTEX are common contaminants of groundwater and there is a potential for other sources.

Consistently higher concentrations in the deeper wells for each of the well pairs, MW-1, 2, and 4, is an interesting feature in the distribution of BTEX. This feature is discussed in more detail in the section on Fate and Transport.

Lindane (gamma-BHC) and its sister BHC compounds were the second most frequently identified group. The next most commonly found chemicals were sister products of gamma-BHC, alpha-, beta-, and delta-BHC at 52, 52, 58 and 48 percent frequency, respectively.

These chemicals were not identified in the most upgradient wells, MW-D and MW-A. However, the distribution in the remaining wells was uneven with the highest concentrations in MW-4D and MW-P which are downgradient of the excavation area. There is not a clear pattern in the distribution.

The remaining chlorinated pesticides, including chlordane, were also depicted on the figures although these chemicals were not frequently identified. There were sporadic identifications of these chemicals across the site but were confined to the site. There were no identifications in the most upgradient (MW-D and MW-A) or most down gradient wells (MW-1 and MW-2).

Dichlorobenzenes and 2-methylnaphthalene were also identified to a lesser extent in groundwater.

Hydropunch® Groundwater Samples

An evaluation of the 21 Hydropunch® samples shows that at least two of the samples are not representative of typical groundwater conditions beneath the site.

No chemicals were identified in 9 of the 21 samples and no chlorinated pesticides were identified in 13 of 21 samples. In the remaining samples, except for two, the concentrations and frequencies of identification are the same as those for the monitoring well samples.

Inspection of Table 5-6 shows that the concentrations and frequency of identifications of the chlorinated pesticides in the Hydropunch® samples are higher than those from the two sets of monitoring well samples by as much as one to two orders of magnitude. Inspection of Table 5-5 shows that these elevated concentrations are a result of two samples, HP-9-S and HP-13-S.

The higher concentrations in these two samples are not expected given the physical characteristics of the chemicals. Comparison of Tables 5-6 and 5-7 shows that 6 chemicals (a-BHC, b-BHC, DDD, DDE, chlordane and dieldrin) are present at concentrations in excess of their solubilities in the two samples. In some cases, the differences are very significant. The maximum concentration of chlordane of 1,100 ug/l is almost 20 times higher than the upper limit of its solubility, 56 ug/l.

There are three possible situations that could results in an apparent or real concentration above the solubility limit:

1. A laboratory artifact resulting from excessively high detection limits and matrix interference (apparent).

2. The presence of high concentrations of solvents resulting in a phenomenon called "co-solvation" (real).

3. The presence of suspended particulates (apparent).

A review of the data shows that the unexpectedly high concentrations are not due to laboratory artifacts. The laboratory data sheets show that the detection limits for these samples were not elevated indicating an absence of matrix effects.

Another possibility is that the more soluble volatile organic chemicals as xylene increased the solubility of the pesticides through a process called "co-solvation". However, studies have shown that concentrations of volatile solvents greater than 100,000 mg/L are needed before solubility limits are exceeded to the degree seen in these samples (Staples and Geiselmann, 1988; Mihelic, 1990).

Therefore, the elevated levels must be due to particulates. There is no way of determining which of the other samples where chemicals were identified is valid. As a result, the discussion focuses on the samples collected from monitoring wells.

Fate and Transport in Groundwater

This section reviews fate and transport of the chemicals in groundwater. The transport of organic chemicals is controlled by their tendency to adhere to soil and/or their solubility in water. Some organic chemicals have a higher affinity for soil than water and remain attached or bound to the soil even as groundwater flows through the soil. Other organic chemicals have a higher affinity for water and will move in the groundwater. These tendencies can be predicted by two characteristics, solubility in water and the Koc parameter. Koc is the ratio of the concentration of the chemical in soil organic matter to that in water.

Solubility measures the chemical's tendency to dissolve in water and Koc measures the tendency to absorb to soil. These values tend to act in an opposite manner:

Mobile chemicals - high solubility and low Koc

Immobile chemicals - low solubility and high Koc

The solubility limits and Koc values for the chemicals identified in groundwater are compiled in Table 5-7. Koc is also dependent on soil organic content. Total organic carbon (TOC) and other soil properties are shown on Table 5-8. Inspection of Table 5-7 shows that the chemicals with the highest solubilities and lowest Koc values, the volatile organic chemicals, are also the most prevalent in groundwater. This is consistent with the theory of mobility.

See Table 5-8

The chemicals with the next highest solubilities and lowest Koc are the dichlorobenzene and BHC isomers. The lower frequencies of identification for dichlorobenzene is consistent with the finding that this group was found less frequently in soil than the BHC isomers. The BHC isomers fall into the category of moderate solubility and mobility. Significant reductions in the soil concentrations will be reflected in reductions in the concentrations in the groundwater.

The least frequently identified chemicals have the lowest solubilities and higher Koc values, chlordane, DDT group, aldrin, dieldrin and endrin. These chemicals show a much stronger tendency to adhere to soil than to dissolve in water. For example, a log Koc of 6.00 means that the concentration in the soil will be 1,000,000 times higher than the concentration in groundwater. Based on the high Koc values and low solubilities, it is unlikely that these chemicals represent a concern to groundwater.

There is a strong possibility that the samples where these chemicals were identified contained suspended soil material. The pesticides may have been bound to the soil material rather than dissolved in the water. Chemicals that are bound to soil are not mobile in groundwater. Only dissolved chemicals move with groundwater flow. The Agency for Toxic Substance and Disease Registry agreed with this evaluation and did not consider chlordane a groundwater concern when they set site-specific cleanup levels.

Both laboratory and field studies have shown that benzene, xylene, ethyl benzene and toluene are susceptible to biodegradation (Hadley and Armstrong, 1991; Howard, 1990).

Aerobic environments, like that created by the removal and fill activities, will enhance the degradation process. There is evidence from the distribution patterns that biodegradation is occurring in the groundwater. In the monitoring well pairs, MW-1, MW-2 and MW-4, the concentration is consistently lower in the shallow wells than the deeper wells while in the wells closer to the center of the site the reverse is true. It is likely that this reversal reflects biodegradation processes which are occurring to a greater extent in the more aerobic shallower zone.

EVALUATION OF CURRENT CONDITIONS

See Table 5-9 and Figure 5-12

This section discusses current conditions at the site now that the sources of chemicals, i.e., soil and free-product, have been removed. During the removal program, 90 to 100 gallons of floating phase and 126,000 gallons of groundwater that contained residual floating phase were removed. Table 5-9 and Figure 5-12 document the extent of soil removal. Table 5-9 shows the percent reduction in soil of the chemicals in the groundwater. Chemical concentrations in the soil have been reduced from 74 to 99 percent with an average reduction of 88 percent. Figure 5-12 depicts the central excavation area and illustrates the concentration of chlordane in soil with depth. This figure shows that chlordane in soil, above and below the water table, was removed.

An evaluation of current conditions indicates that the sources of the chemicals in groundwater have been removed, in particular for the two most-prevalent groups of chemicals, BTEX and BHC sisters. In addition, BTEX chemicals are susceptible to biodegradation, especially the chemical of most concern to human health--benzene. Inspection of Table 5-9 shows that BHC concentrations were reduced in the soil from 81 to 87 percent. Reductions of other chemicals ranged from 74 to 94 percent.

At this time, there is insufficient data to determine the nature and extent of any residual chemicals in groundwater. Also, there is uncertainty regarding potential upgradient sources. Review of aerial photographs shows automotive operations southwest and upgradient of the site. There are reports that underground storage tank(s) were removed, potentially in two locations. Evidence of a temporary monitoring well was observed in an apparent excavation area at another location immediately south of the site.

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Table 5-1 October 1991 Groundwater Depth Data

Well No.	TOC Elevation	Well Depth	Screened Interval	Depth to Water	Water Elevation
MW-A	104.92	17	7-17	10.67	94.25
MW-D	102.46	17	7-17	6.63	95.83
MW-E	103.26	17	7-17	8	95.26
MW-F	103.41	32.5	22.5-32.5	8.68	94.73
MW-G	102.66	32.5	22.5-32.5	n/m	
MW-H	102.54	17	7-17	n/m	
MW-I	102.06	17	7-17	6.96	95.10
MW-J	102.28	17	7-17	7.93	94.35
MW-K	102.32	33.5	23.5-33.5	8.65	93.67
MW-L	102.36	17	7-17	8.69	93.67
MW-M	103.58	22	12-22	11.25	92.33
MW-N	102.72	17	7-17	8.46	94.26
MW-O	103.92	17	7-17	n/m	
MW-P	103.86	22	12-22	12.46	91.40
MW-1S	101.17	15	5-15	9.83	91.34
MW-1D	101.18	30	20-30	9.75	91.43
MW-2S	99.5	15	5-15	5.9	93.60
MW-2D	99.5	30	20-30	6	93.50
MW-3S	99.31	15	5-15	4.78	94.53
MW-3D	99.19	30	20-30	4.94	94.25
MW-4S	102.52	15	5-15	9.12	93.40
MW-4D	101.9	30	20-30	8.61	93.29

TOC - Top of Casing
n/m - Not measured

Table 5-2 Groundwater Investigation--Slug Test Results

Monitor Well	Hydraulic conductivity (k)
MW-1S	4.66 FT/DAY
MW-1D	5.62 FT/DAY
MW-2S	1.82 FT/DAY
MW-2D	3.28 FT/DAY
MW-4S	1.92 FT/DAY
MW-4D	6.74 FT/DAY
MW-O	5.78 FT/DAY
MW-L	1.95 FT/DAY
MW-K	2.25 FT/DAY

Table 5-3 Analytical Results of Monitoring Wells--September 1990

Parameter	Units	Well Identification MW-A	DUP-A	MW-D	DUP-D	MW-E	MW-F	MW-G	MW-H
Benzene	ug/l	<1	<1	<1	<1	<100	<1	<50	97
Toluene	ug/l	<1	<1	<1	<1	<100	15	<50	76
Xylene	ug/l	<1	<1	<1	<1	2500	<1	920	1300
Ethylbenzene	ug/l	<1	<1	<1	<1	540	5.7	180	220
a-BHC	ug/l	<.01	<.01	<.01	<.01	<.50	5.1	.37	2.4
b-BHC	ug/l	<.01	<.01	<.01	<.01	.86	2.1	.14	7.7
d-BHC	ug/l	<.01	<.01	<.01	<.01	<.50	4.2	.29	<.50
g-BHC	ug/l	<.01	<.01	<.01	<.01	<.50	.44	.18	1.7
Aldrin	ug/l	<.01	<1	.01	.01	<.50	<.20	<1	<.50
Dieldrin	ug/l	<.02	<1	<.02	<.02	<1	.67	<.20	<1
Endrin	ug/l	<.02	<1	<.02	<.02	<1	<.40	<.20	<1
4,4-DDD	ug/l	<.02	<1	<.02	<.02	<1	<3.9	<.20	2.6
Endosulfan I	ug/l	<.02	<.02	.023	.025	<1	1.5	.3	<1
Heptachlor	ug/l	<.01	<.01	<.10	<.10	<.50	.26	<.10	<.50
Chlorobenzene	ug/l	<1	<1	<1	<1	<1	5.1	<50	130
Chloroform	ug/l	<1	<1	<1	<1	<1	2.8	<50	<25
1,4-Dichlorobenzene	ug/l	<1	<1	<1	<1	<1	<60	<50	72
1,1-Dichloroethane	ug/l	<1	<1	<1	<1	<1	1.2	<50	<25
1,2-Dichloroethane	ug/l	<1	<1	<1	<1	<1	<1	<50	56
1,1-Dichloroethene	ug/l	<1	<1	<1	<1	<1	1.8	<50	48
Methylene Chloride	ug/l	<1	<1	<1	<1	<1	<1	<50	290
1,1,2-Trichloroethane	ug/l	<1	<1	<1	<1	<1	<1	<50	220

Table 5-3 Analytical Results of Monitoring Wells--September 1990

Parameter	Well Identification								
	DUP-H	MW-I	MW-J	MW-K	MW-L	MW-M	MW-N	MW-O	MW-P
Benzene	54	<25	62	<5	<5	<1	<1	<25	<1
Toluene	54	<25	88	<5	<5	<1	<1	<25	<1
Xylene	640	730	750	89	<5	<1	<1	420	<1
Ethylbenzene	130	350	140	39	<5	<1	1.5	<25	<1
a-BHC	2.8	<.20	15	.10	2.1	.03	3.6	21	4.5
b-BHC	8.2	.36	7.1	.10	1.4	.10	2.9	52	22
d-BHC	.25	.23	11	.10	<.20	.02	5.8	21	5.9
g-BHC	1.7	<.20	18	.10	.67	.04	.82	17	1.5
Aldrin	<.50	<.20	<.50	<.20	1.7	<.01	<.10	<1	13
Dieldrin	<1	.57	<1	<.40	<.40	.07	<.20	<2	<1
Endrin	1.5	<.40	1.1	<.40	<.40	.02	<.20	<2	<1
4,4-DDD	5.5	1	4.6	<.40	<.40	<.02	.59	<2	<1
Endosulfan I	<1	<.40	<1	<.40	<.40	<.02	<.20	<1	<2.5
Heptachlor	<.50	<.20	<.50	<.20	<.20	<.01	.13	<1	<.5
Chlorobenzene	120	<25	130	<5	<100	<1	2.7	<25	<1
Chloroform	<25	<25	<50	<5	<100	<1	<1	<25	<1
1,4-Dichlorobenzene	80	<25	150	<5	49	<1	1.5	<25	<1
1,1-Dichloroethane	<25	<25	<50	<5	<100	<1	<1	<25	<1
1,2-Dichloroethane	<25	<25	<50	<5	<100	<1	<1	<25	<1
1,1-Dichloroethene	55	<25	120	<5	<100	<1	<1	<25	<1
Methylene Chloride	68	<25	<50	<5	<100	<1	<1	<25	<1
1,1,2-Trichloroethane	39	<25	<50	<5	<100	<1	<1	<25	<1

Table 5-4 October Groundwater Sampling Results--December 1991

Parameter	Units	MW-1D	MW-2D	MW-3D	MW-4D	MW-1S	MW-2S	MW-3S	MW-4S	MW-A	MW-D	MW-E
Benzene	ug/l	0.30	0.30	30.00	1.50	1.50	55.00	3.10	25.00	0.30	0.30	6.90
Toluene	ug/l	0.50	0.50	50.00	2.50	12.00	74.00	2.50	18.00	0.50	0.50	0.50
Ethylbenzene	ug/l	0.45	0.45	2500.00	14.00	490.00	210.00	200.00	390.00	0.45	0.45	2.90
Xylene	ug/l	0.45	0.45	15000.00	25.00	700.00	1200.00	470.00	2000.00	0.45	0.45	110.00
AVERAGE		0.425	0.425	4395	10.75	300.875	384.75	168.9	608.25	0.425	0.425	30.075
sum		1.7	1.7	17580	43	1203.5	1539	675.6	2433	1.7	1.7	120.3
a-BHC	ug/l	0.03	0.03	0.25	0.40	0.03	3.50	0.03	0.50	0.03	0.77	3.80
b-BHC	ug/l	0.03	0.03	0.25	0.25	0.03	2.10	0.03	0.50	0.03	1.60	5.70
d-BHC	ug/l	0.03	0.03	0.25	0.03	0.03	5.10	0.03	0.50	0.03	0.48	2.80
g-BHC	ug/l	0.03	0.03	0.25	1.30	0.03	5.70	0.03	0.50	0.03	4.50	5.50
avg		0.025	0.025	0.25	0.49375	0.025	4.1	0.025	0.5	0.025	1.8375	4.45
sum		0.1	0.1	1	1.975	0.1	16.4	0.1	2	0.1	7.35	17.8
Aldrin	ug/l	0.03	0.03	2.50	0.03	0.03	1.25	0.03	0.50	0.03	0.08	1.25
4,4'-DDD	ug/l	0.15	0.15	1.50	0.15	0.15	7.50	0.15	3.00	0.15	1.40	7.50
4,4-DDE	ug/l	0.50	0.50	0.50	0.05	0.05	2.50	0.05	1.00	0.05	0.15	2.50
average	ug/l	0.325	0.325	1	0.1	0.1	5	0.1	2	0.1	0.775	5
sum	ug/l	0.65	0.65	2	0.2	0.2	10	0.2	4	0.2	1.55	10
Chlordane	ug/l	1.00	1.00	10.00	3.30	1.00	50.00	1.00	20.00	10.00	6.50	50.00

Table 5-4 October Groundwater Sampling Results--December 1991

MW-F	MW-I	MW-J	MW-K	MW-L	MW-M	MW-N	MW-P	Average	Maximum	Minimum	% Reduction	Est. Avg. Conc. After Removal
5.40	0.30	1.50	0.60	0.60	5.70	0.60	17.00	8.21	55	0.3	0	8.21
2.00	0.50	2.50	1.00	1.00	5.20	1.00	10.00	9.72	74	0.5	93	0.68
53.00	0.45	120.00	0.90	67.00	240.00	96.00	360.00	249.79	2500	0.45	83	42.46
55.00	0.45	930.00	0.90	520.00	600.00	1100.00	1100.00	1253.32	15000	0.45	82	225.60
28.85	0.425	263.5	0.85	147.15	212.725	299.4	371.75					
115.4	1.7	1054	3.4	588.6	850.9	1197.6	1487					
0.26	0.03	0.08	1.30	0.50	0.68	0.13	3.20	0.82	3.8	0.025	93	0.06
0.40	0.03	0.61	1.60	0.50	0.25	0.13	4.90	1.00	5.7	0.025	94	0.06
0.07	0.03	0.07	0.03	0.50	0.25	0.13	1.25	0.61	5.1	0.025	94	0.04
0.97	0.03	0.07	5.90	0.50	0.25	0.13	13.00	2.04	13	0.025	92	0.16
0.425	0.025	0.20625	2.20625	0.5	0.3575	0.125	5.5875					
1.7	0.1	0.825	8.825	2	1.43	0.5	22.35					
0.07	0.03	0.22	0.03	0.50	0.25	0.13	1.25	0.43	2.5	0.025	89	0.05
0.07	0.15	1.80	0.15	3.00	1.50	0.75	7.50	1.93	7.5	0.07	78	0.43
0.07	0.05	0.74	0.05	1.00	0.50	0.25	2.50	0.68	2.5	0.05	92	0.05
0.07	0.1	1.27	0.1	2	1	0.5	5					
0.14	0.2	2.54	0.2	4	2	1	10					
3.00	1.00	5.80	1.00	20.00	10.00	5.00	50.00	13.14	50	1	99	0.13

Table 5-5 Hydropunch Data--September 1991

Parameter	Units	HP-1-S	HP-1-D	HP-2-S	HP-3-S	HP-5-S	HP-6-S	HP-7-S	HP-8-S	8S-DUP	HP-9-S
Organochlorine Pesticides											
a-bhc	ug/l	<1	<1	<1	<1	<1	<1	<1	<1	3	2100
b-bhc	ug/l	3.6	<1	<1	<1	<1	<1	<1	<1	49	460
g-bhc	ug/l	<1	3	<1	<1	<1	<1	<1	<1	<1	2500
d-bhc	ug/l	3.6	<1	<1	<1	<1	<1	<1	<1	23	<1
Heptachlor	ug/l	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Aldrin	ug/l	<1	<1	<1	<1	<1	<1	<1	<1	5	<1
Dieldrin	ug/l	2.4	<1	<1	<1	<1	<1	<1	<1	<1	3800
Endrin	ug/l	95	<1	2.4	<1	<1	<1	<1	<1	<1	<1
4,4-DDD	ug/l	5	<1	<1	<1	<1	<1	<1	<1	<1	49000
4,4-DDT	ug/l	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
4,4-DDE	ug/l	2.6	<1	<1	<1	<1	<1	<1	<1	<1	5100
Chlordane	ug/l	41	<7.5	<7.5	<7.5	<7.5	<7.5	<7.5	<7.5	<7.5	<7.5
Volatile Aromatics											
Methyl-tert-butyl-ether	ug/l	<4.5	<4.5	<0.45	<0.45	<0.9	<0.45	<2.25	<0.45	<0.45	<4.5
Benzene	ug/l	<3	<3	<0.3	<0.3	<0.6	<0.3	<1.5	3	3.7	17
Toluene	ug/l	<5	<5	<0.5	<0.5	<1	<0.5	<2.5	1.3	<0.5	250
Chlorobenzene	ug/l	<6.5	<6.5	<6.5	<0.65	5.5	<0.65	<3.25	4.5	<0.65	2100
Ethylbenzene	ug/l	14	<4.5	<0.45	<0.45	<0.9	<0.45	<2.25	<0.45	<0.45	15000
Xylenes	ug/l	<4.5	<4.4	<0.45	<0.45	<0.9	<0.45	<2.25	4.3	6.4	<4.5
1,3-Dichlorobenzene	ug/l	5.5	<5.5	<0.55	<0.55	7.4	<0.55	<2.75	<0.55	<0.55	<5.5
1,4-Dichlorobenzene	ug/l	<5	<5	<0.5	<0.5	<1	<0.5	<2.5	<0.5	<0.5	<5
1,2-Dichlorobenzene	ug/l	<5	<5	<0.5	<0.5	<0.5	<0.5	<2.5	<0.5	<0.5	<5

Table 5-5 Hydropunch Data--September 1991

Parameter	Units	HP-9-D	HP-10-S	HP-10-D	HP-11-S	HP-11-D	HP-12-S	HP-13-S	HP-14-S	Avg. Hits
Organochlorine Pesticides										
a-bhc	ug/l	5.2	<1	<1	<1	<1	<1	170	0.18	120.65
b-bhc	ug/l	2	<1	<1	<1	<1	<1	<1	<0.025	27.82
g-bhc	ug/l	4.4	<1	<1	<1	<1	<1	<1	<0.025	132.76
d-bhc	ug/l	15	<1	<1	<1	<1	<1	310	<0.3	19.26
Heptachlor	ug/l	<1	<1	<1	<1	<1	<1	<1	0.52	0.97
Aldrin	ug/l	<1	<1	<1	<1	<1	<1	<1	1.1	1.22
Dieldrin	ug/l	4.2	<1	<1	<1	<1	<1	22	2	202.35
Endrin	ug/l	<1	<1	<1	<1	<1	<1	<1	1.1	6.03
4,4-DDD	ug/l	33	<1	<1	<1	<1	<1	<1	0.8	2581.78
4,4-DDT	ug/l	2.8	<1	<1	<1	<1	<1	<1	0.15	1.05
4,4-DDE	ug/l	2.7	<1	<1	<1	<1	<1	<1	<0.05	269.49
Chlordane	ug/l	18	<7.5	<7.5	<7.5	<7.5	<7.5	1100	7.5	67.32
Volatile Aromatics										
Methyl-tert-butyl-ether	ug/l	<4.5	<0.45	<0.9	<0.45	<4.5	<4.5	<4.5	<0.45	2.08
Benzene	ug/l	<3	<0.3	<0.6	<0.3	<3	<3	12	<0.3	2.78
Toluene	ug/l	<5	<0.5	<1	<0.5	<5	<5	25	<0.5	16.31
Chlorobenzene	ug/l	24	<0.65	<1.3	<6.5	<6.5	<6.5	5.5	<0.65	115.10
Ethylbenzene	ug/l	20	<0.45	24	<0.45	17	14	160	<0.45	803.19
Xylenes	ug/l	230	<0.45	150	<0.45	100	110	1900	<0.45	132.65
1,3-Dichlorobenzene	ug/l	<5.5	<0.55	<1.1	<0.55	<5.5	<5.5	<5.5	<0.55	2.88
1,4-Dichlorobenzene	ug/l	<5	<0.5	<1	<0.5	<5	<5	15	<0.5	2.84
1,2-Dichlorobenzene	ug/l	<5	<0.5	<1	<0.5	<5	<5	<5	<0.3	2.28

Table 5-6 Summary of Sample Results for Groundwater

Analyte	MONITORING WELL SAMPLES September 1990 No. of Analyses/ Detections	Maximum	Average (ug/l)	MONITORING WELL SAMPLES October 1991 No. of Analyses/ Detections	Maximum	Average (ug/l)	HYDROPUNCH SAMPLES October 1991 No. of Analyses/ Detections	Maximum	Average (ug/l)
4,4-DDD	13/2	5.5	1	18/2	7.5	0.2	21/4	49000	2336
4,4-DDT	13/0	-	-	18/0	-	-	21/1	2.8	1.1
4,4-DDE	13/0	-	-	18/0	2.5	-	21/3	5100	243.9
a-BHC	13./8	21	4.2	18/8	3.8	0.71	21/5	2100	109.3
b-BHC	13/10	52	7.4	18/8	5.7	0.9	21/4	460	25.3
g-BHC	13/8	21	3.8	18/3	5.1	0.4	21/3	2500	120.2
d-BHC	13/8	18	3.1	18/7	13	1.9	21/5	310	17.5
Aldrin	13/2	13	1.3	18/1	2.5	0.01	21/2	5	1.2
Chlordane	13/0	-	-	18/3	50	0.8	21/4	1100	61.6
Dieldrin	13/3	1	0.4	18/0	-	-	21/5	3800	183.2
Endrin	13/2	5	0.4	18/0	-	-	21/3	95	5.6
Heptachlor	n/a	-	n/a	-	-	n/a	21/1	0.52	1
1,2-Dichlorobenzene	13/0	-	-	18/6	55	56.2	21/0	-	-
1,3-Dichlorobenzene	n/a	-	-	n/a	-	-	21/1	7.4	2.9
1,4-Dichlorobenzene	13/3	150	25.2	18/6	530	56.2	21/1	15	2.8
2-Methylnaphthalene	13/0	-	-	18/5	76	8.4	n/a	-	-
Benzene	13/2	97	17.9	18/7	55	6.2	21/0	17	2.7
Chlorobenzene	13/4	-	28.6	18/7	-	17.2	21/4	2100	104.2
Ethylbenzene	13/7	930	145	18/13	2500	250	21/3	15000	729.6
Methyl-tert-butyl-ether	13/0	-	-	18/1	-	0.3	21/0	-	-
Toluene	13/2	88	16.9	18/6	74	6.4	21/8	250	15
Xylenes	13/8	5500	940	18/13	15000	1253	21/8	1900	139.1

Average calculated using 1/2 the detection limit where not detected.

Table 5-7 Summary Table--Organic Chemicals in Groundwater

Analyte	Log[a] koc	Solubility,[a] (mg/l)	Frequency of detection in monitoring well samples
4,4-DDD[b]	5.99 - 6.08	0.020 - 0.16	13
4,4-DDE	5.4 - 6.0	0.014 - 0.04	0
4,4-DDT[b]	5.14 - 6.26	0.031 - 0.053	3
a-BHC	3.3	1.2 - 2.0	52
b-BHC	3.3 - 3.5	0.13 - 0.20	58
g-BHC	2.8 - 3.5	0.15 - 7.8	52
d-BHC	3.3	8.6 - 15.7	48
Aldrin[b]	-	0.011 - .180	13
Chlordane[b]	5.15-5.57	.009 - .056	13
Dieldrin[b]	4.55	.05 - .2	6
Endrin	3.92	.19 - .26	13
2-Methylnaphthalene	3.93	24.6 - 25.4	16
1,2-dichlorobenzene	2.27 - 3.23	100 - 156	19
1,4-dichlorobenzene	2.20	49 - 91	29
Benzene	1.69 - 2.00	1,790 - 1,850	29
Chlorobenzene	1.68	295 - 500	35
Ethylbenzene	1.98 - 2.41	140 - 208	65
Toluene	2.18 - 2.06	490 - 524	26
Xylenes	2.11	142 - 213	68

[a] John H. Montgomery and Linda M. Welkom, Groundwater Chemicals Desk Reference, Lewis Publishers, Chelsea, Michigan, 1990.

[b] The high Koc of this chemical suggests its presence in groundwater may be due to suspended particulate.

RAR\6434T5-7

Table 5-8 Soil Data--June 1991

Sample location, I.D.	Depth interval, feet	TOC,[a] mg/kg	Total density, pfc	Dry density, pfc	Porosity, percent
SPT-32-01	2 - 4	5,300	--	--	--
SPT-46-01	2 - 4	3,800	--	--	--
SPT-58-01	2 - 4	820	--	--	--
SPT-48-2.5	6 - 8	410	125.7	102.0	60
SPT-20-2.5	6 - 8	720	126.2	97.6	57
SPT-25-2.5	6 - 8	520	119.5	101.0	60

[a] Total organic carbon.

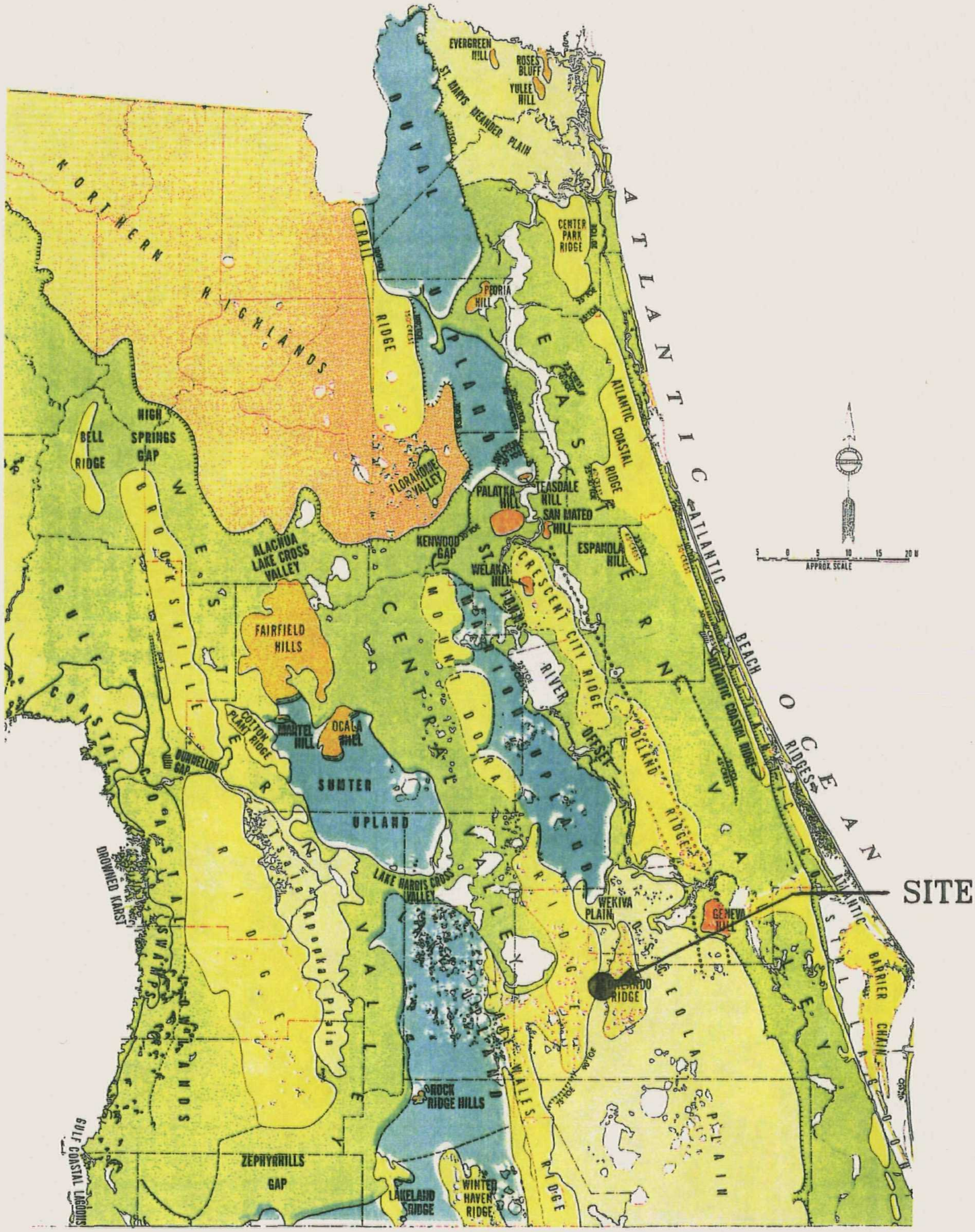
RAR\6434T5-8

Table 5-9 Summary Table

Analyte	Frequency of detection in monitoring well samples	Average percent reduction in soil
4,4-DDD[b]	13	74
4,4-DDE	0	85
4,4-DDT[b]	3	85
a-BHC	52	87
b-BHC	58	83
g-BHC	52	81
d-BHC	48	84
Aldrin[b]	13	78
Chlordane[b]	13	93
Dieldrin[b]	6	79
Endrin	13	84
2-Methylnaphthalene	16	90
1,2-dichlorobenzene	19	94
1,4-dichlorobenzene	29	91
Benzene	29	[c]
Chlorobenzene	35	86
Ethylbenzene	65	89
Methyl-tert-butyl-ether	3	[c]
Toluene	26	91
Xylenes	68	87

[a] John H. Montgomery and Linda M. Welkom, Groundwater Chemicals Desk Reference, Lewis Publishers, Chelsea, Michigan, 1990.
[b] The high Koc of this chemical suggests its presence in groundwater may be due to suspended particulate.
[c] Too few detections/analyses in soil to estimate percent removal.

RAR\6434T5-9



Source: White, W. A., The Geomorphology of the Florida Peninsula, State of Florida Department of Natural Resources, Bureau of Geology, Bulletin No. 51. 1970.

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Figure 5-1
Physiographic Map of Central Florida

Series	Stratigraphic and hydrologic units		Lithology
Holocene	Undifferentiated alluvium and terrace deposits	Surficial aquifer system	Sand with local shell beds
Pleistocene[1]	Pamlico Sand		Fine to medium sand
	Miami Oolite		Oolitic limestone
	Fort Thompson Formation		Interbedded sand, shell, and limestone
	Anastasia Formation		Sandy limestone and marl
Pliocene	Caloosahatchee Marl		Marl with minor sand and silt
	Tamiami Formation		Marl with beds of fossiliferous limestone
	Bone Valley Formation		Phosphatic sand and clay
Miocene	Choctawhatchee Formation		Sand and limestone

Figure 5-2b
Formations Comprising the Surficial Aquifer
(Note: This is a generalized stratigraphic column, not all formations are present beneath the site.)

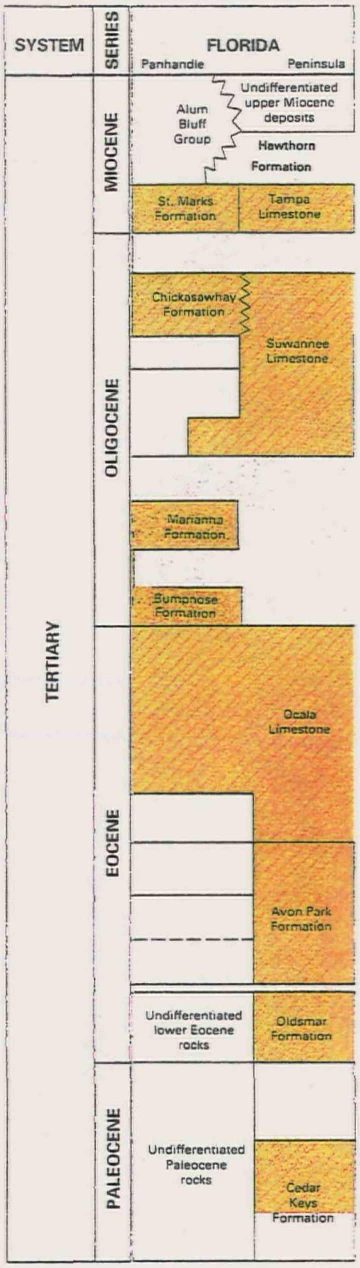

Figure 5-2a
Formations Comprising the Floridan Aquifer.
(Note: Grey areas indicate missing formations.)

Source:
Miller, James A., 1990, Groundwater Atlas of the United States, Segment 6, U.S. Department of the Interior, United States Geological Survey

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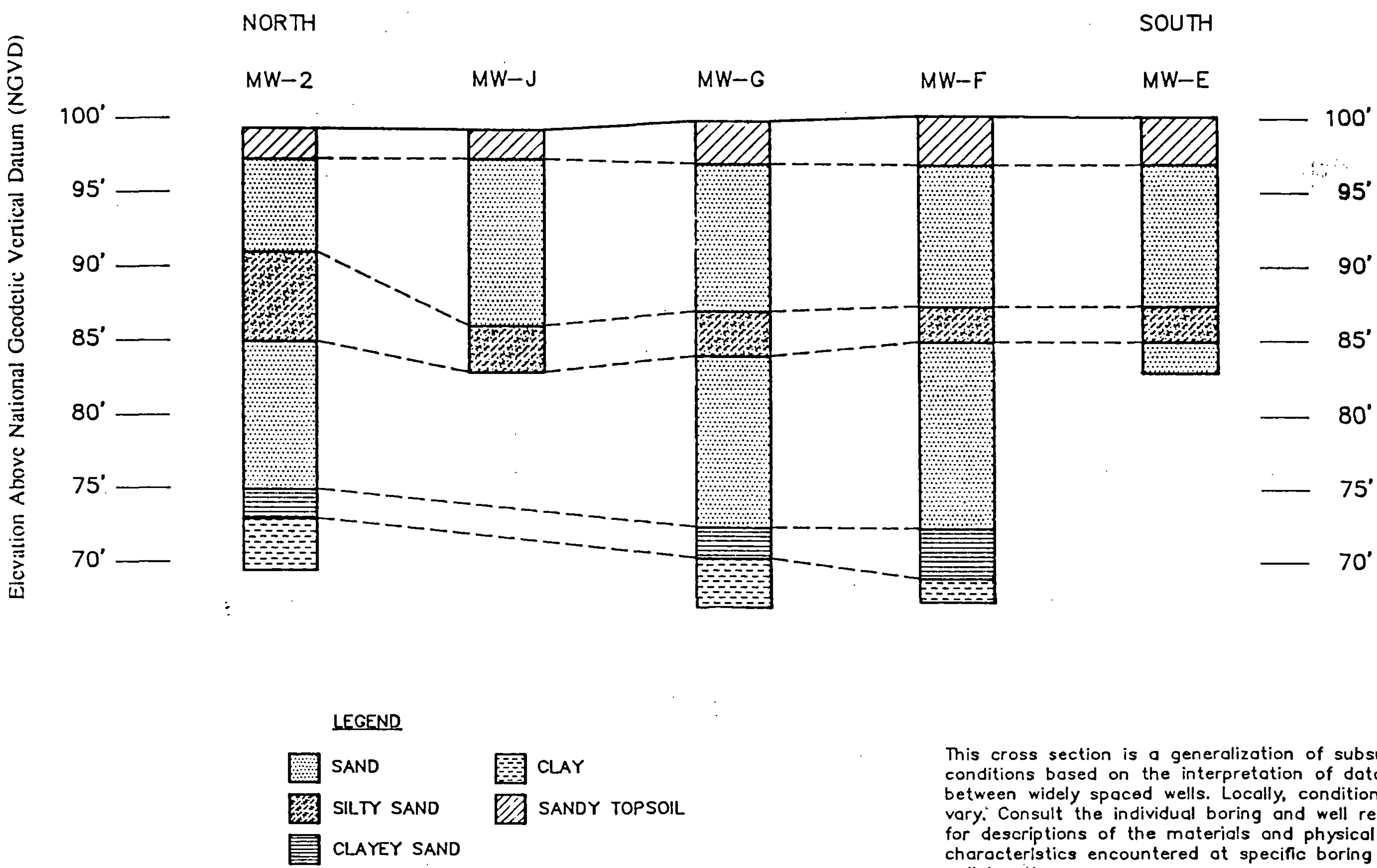
Figure 5-2
Stratigraphic Columns



This cross section is a generalization of subsurface conditions based on the interpretation of data between widely spaced wells. Locally, conditions may vary. Consult the individual boring and well records for descriptions of the materials and physical characteristics encountered at specific boring and well locations.

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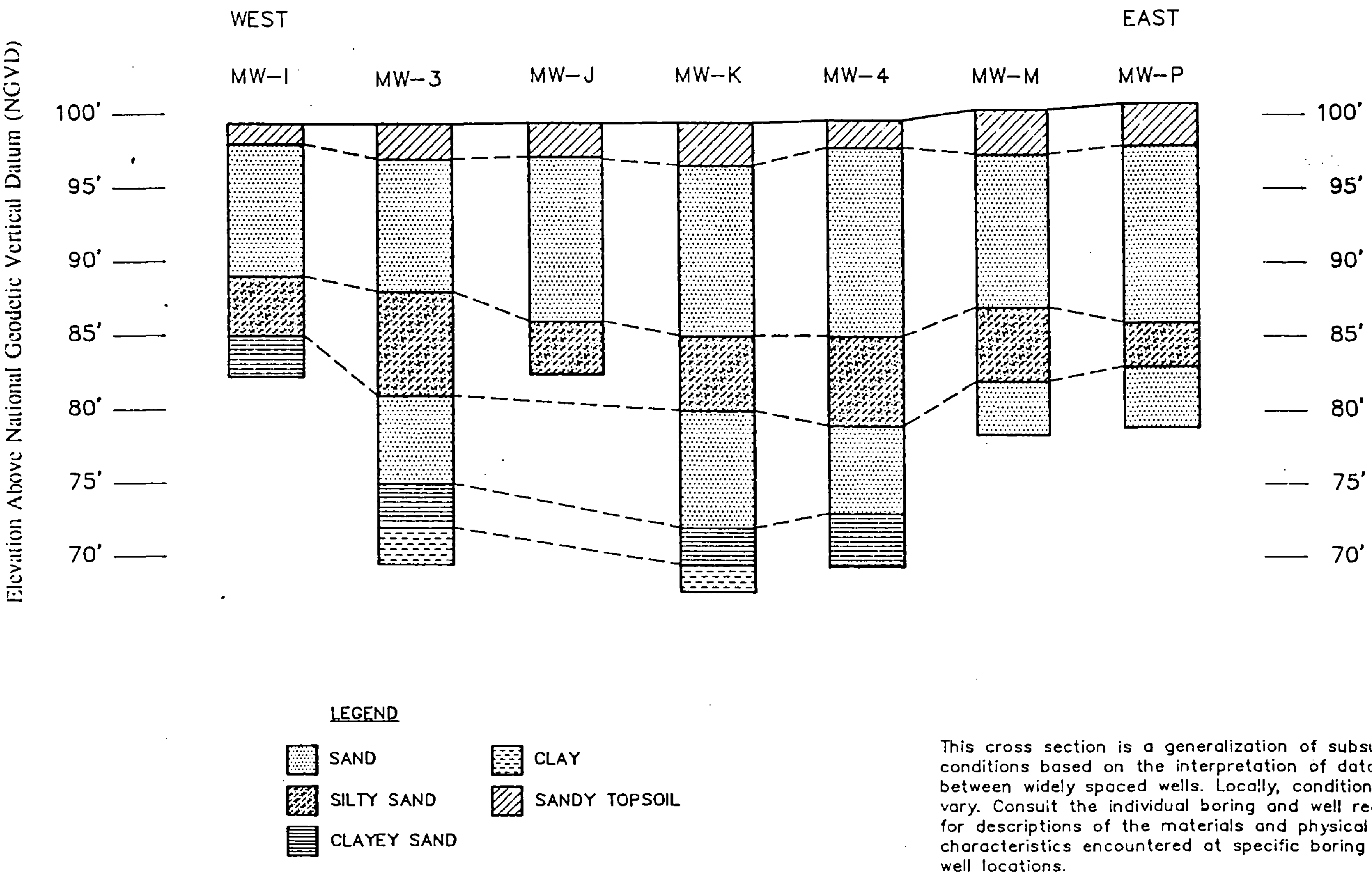
Figure 5-3
North-South Geologic Cross Section



This cross section is a generalization of subsurface conditions based on the interpretation of data between widely spaced wells. Locally, conditions may vary. Consult the individual boring and well records for descriptions of the materials and physical characteristics encountered at specific boring and well locations.

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Figure 5-4
East-West Geologic Cross Section

The surficial aquifer system extends throughout large areas in the Coastal Plain of Florida, Georgia, and South Carolina.

Source: Miller, James A., 1990, Groundwater Atlas of the United States, Segment 6, U.S. Department of the Interior, United States Geological Survey.

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Figure 5-6
Extent of the Surficial Aquifer System

The carbonate rocks of the Floridan aquifer system underlie all of Florida, most of the Coastal Plain of Georgia, and extend for short distances into Alabama and South Carolina.

Source: Miller, James A., 1990, Groundwater Atlas of the United States, Segment 6, U.S. Department of the Interior, United States Geological Survey.

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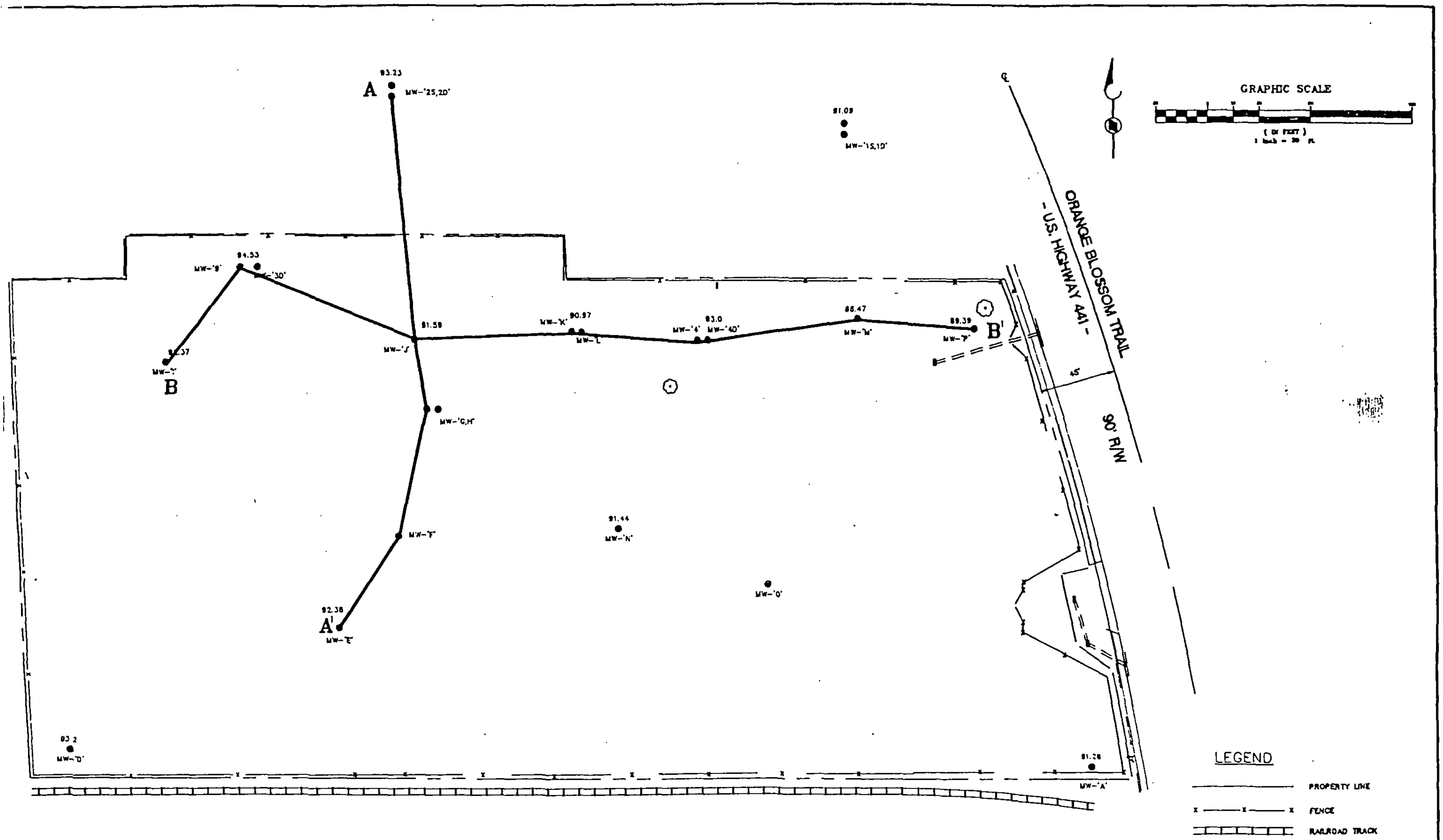
Figure 5-7
Extent of the Floridan Aquifer System



NOTES:
A–A' – LOCATION OF NORTH–SOUTH GEOLOGIC CROSS SECTION SHOWN ON FIGURE 4–4.
B–B' – LOCATION OF EAST–WEST GEOLOGIC CROSS SECTION SHOWN ON FIGURE 4–5.

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Figure 5-4a
Location of Geologic Cross Sections

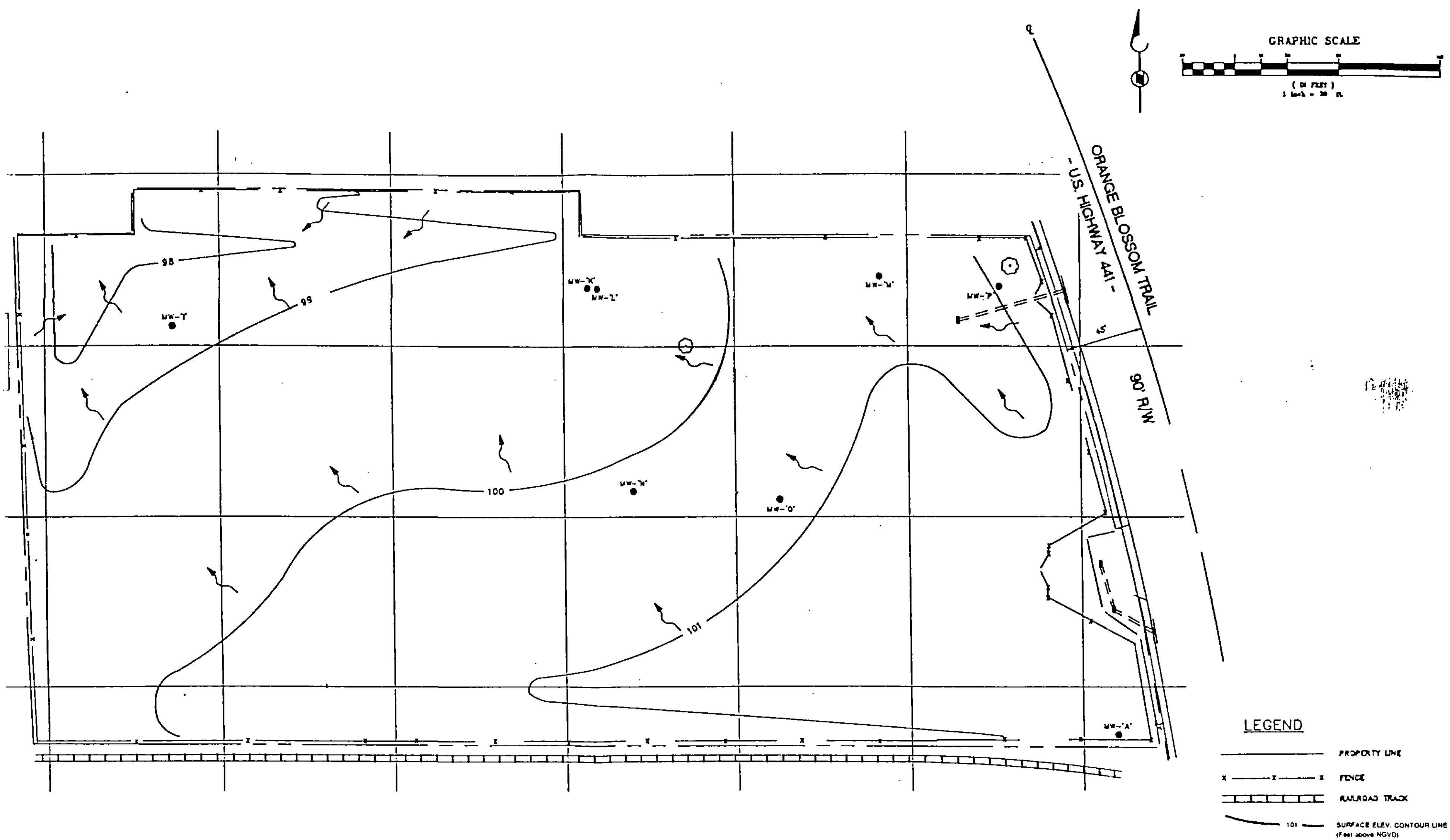

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Figure 5-5
Final Site Drainage Features

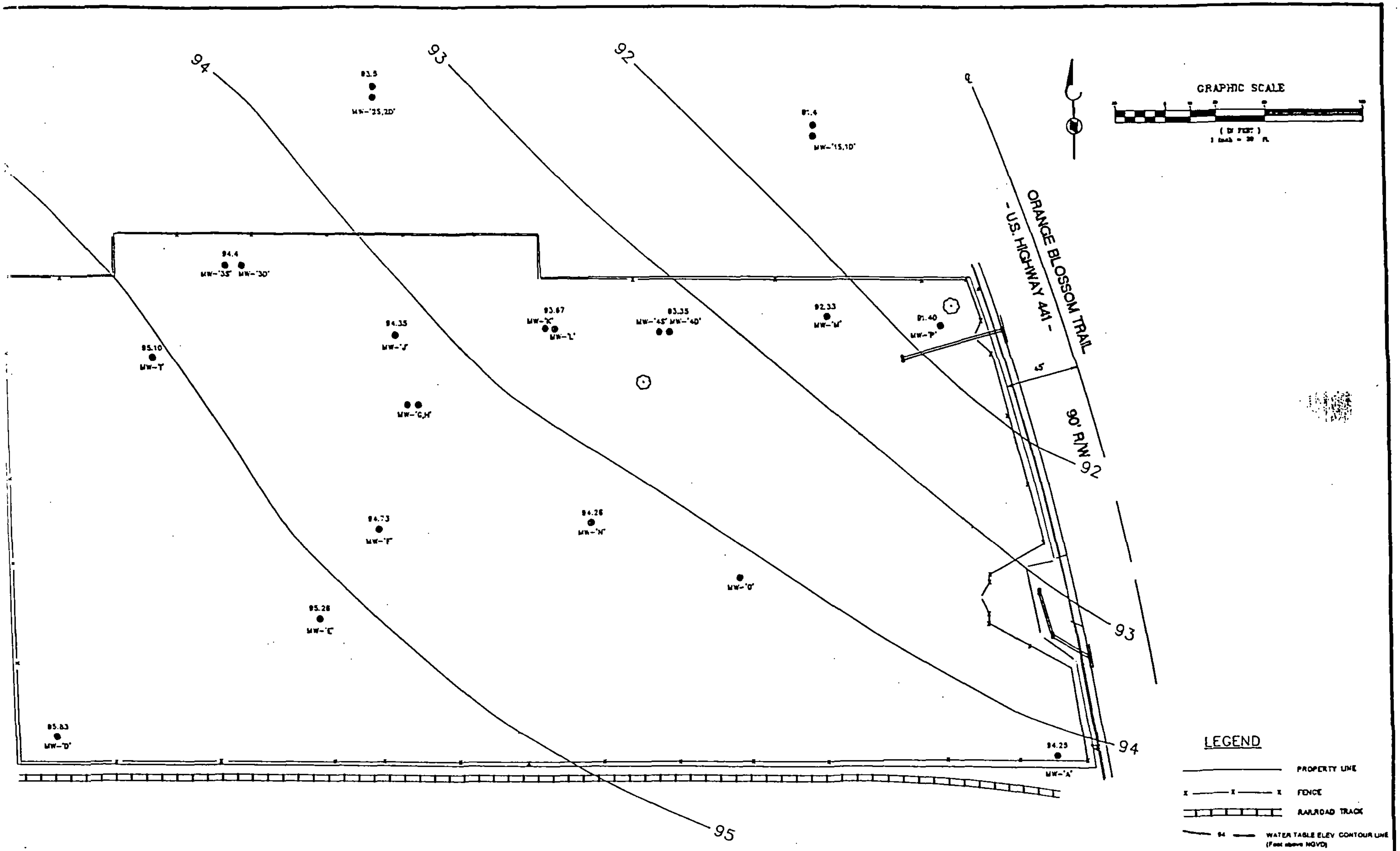

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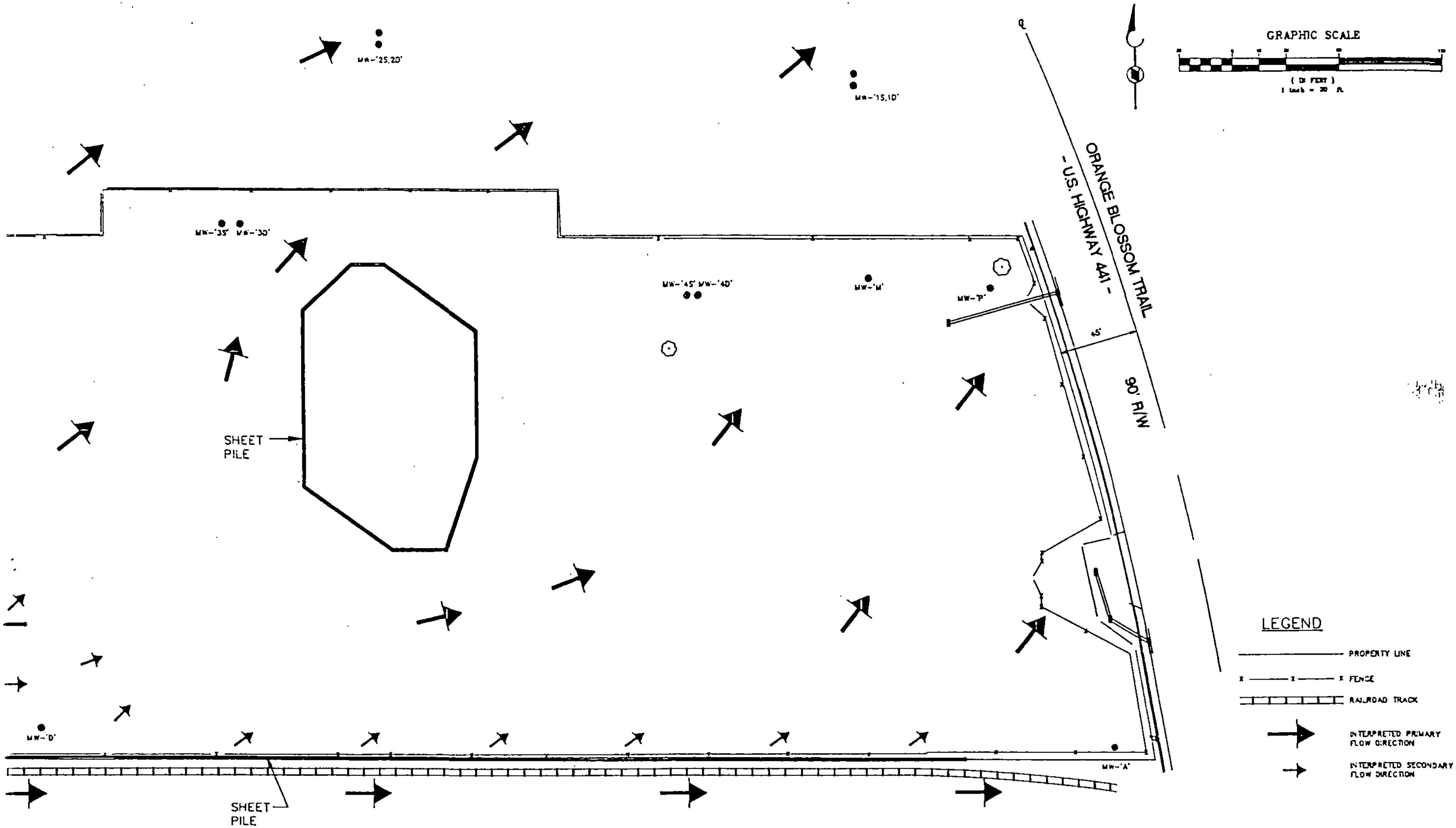
Figure 5-8
Water Table Elevation
October, 1991



NOTE:
THIS FIGURE IS AN INTERPRETATION BASED IN PART ON ASSUMED GROUNDWATER CONDITIONS, THE EFFECTS OF REMOVAL OPERATIONS AND PROFESSIONAL JUDGEMENT. IT IS INTENDED FOR ILLUSTRATIVE PURPOSES ONLY.

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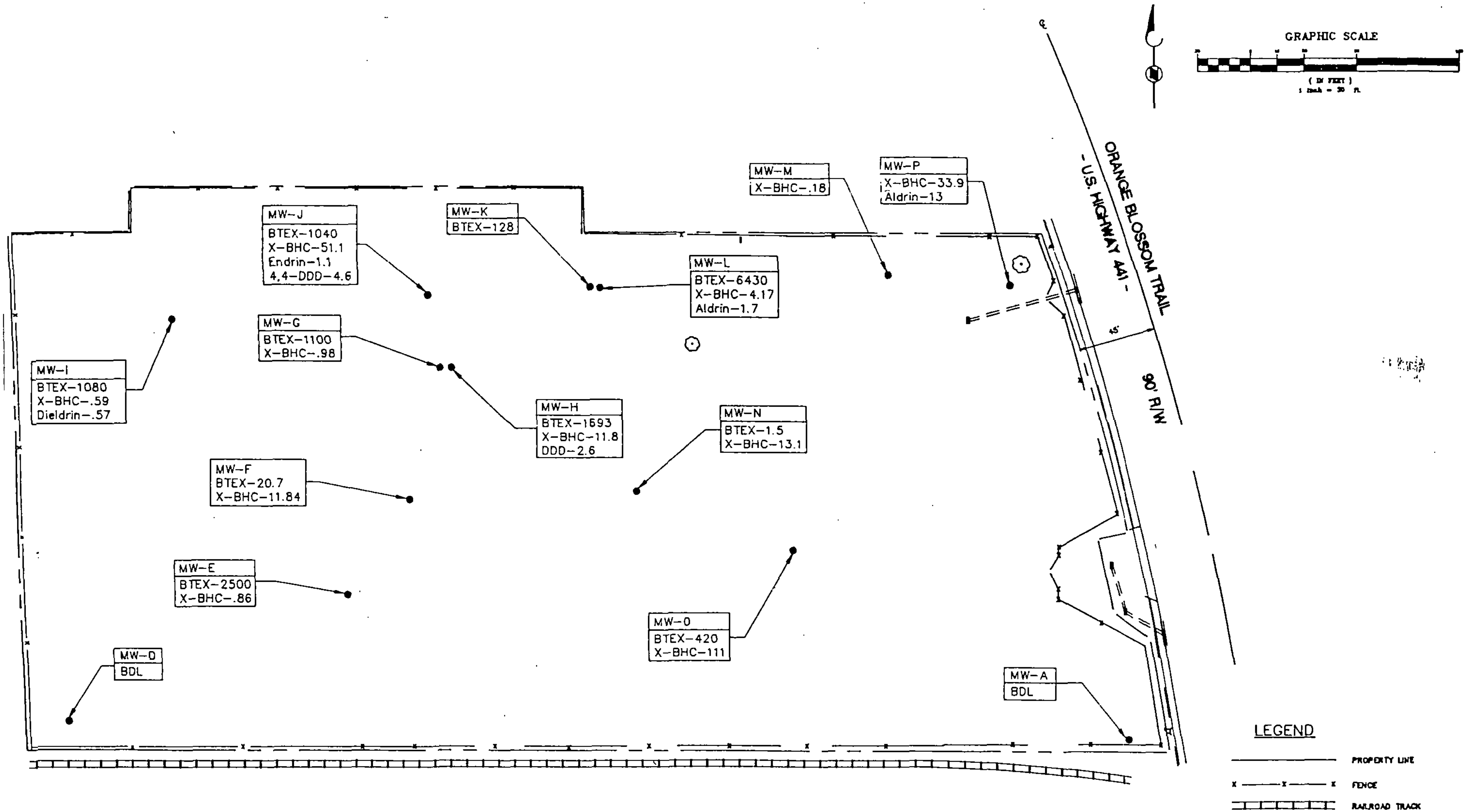
Figure 5-9
Conceptual Post-Removal Shallow Groundwater Flow and Remaining Monitoring Wells



NOTES:
1) X-BHC = SUM OF ALL ISOMERS OF LINDANE DETECTED
2) BTEX = SUM OF BENZENE, TOLUENE, ETHYLBENZENE AND XYLENE
3) BDL = ALL ANALYTES BELOW DETECTION LIMITS
4) ALL UNITS IN UG/L

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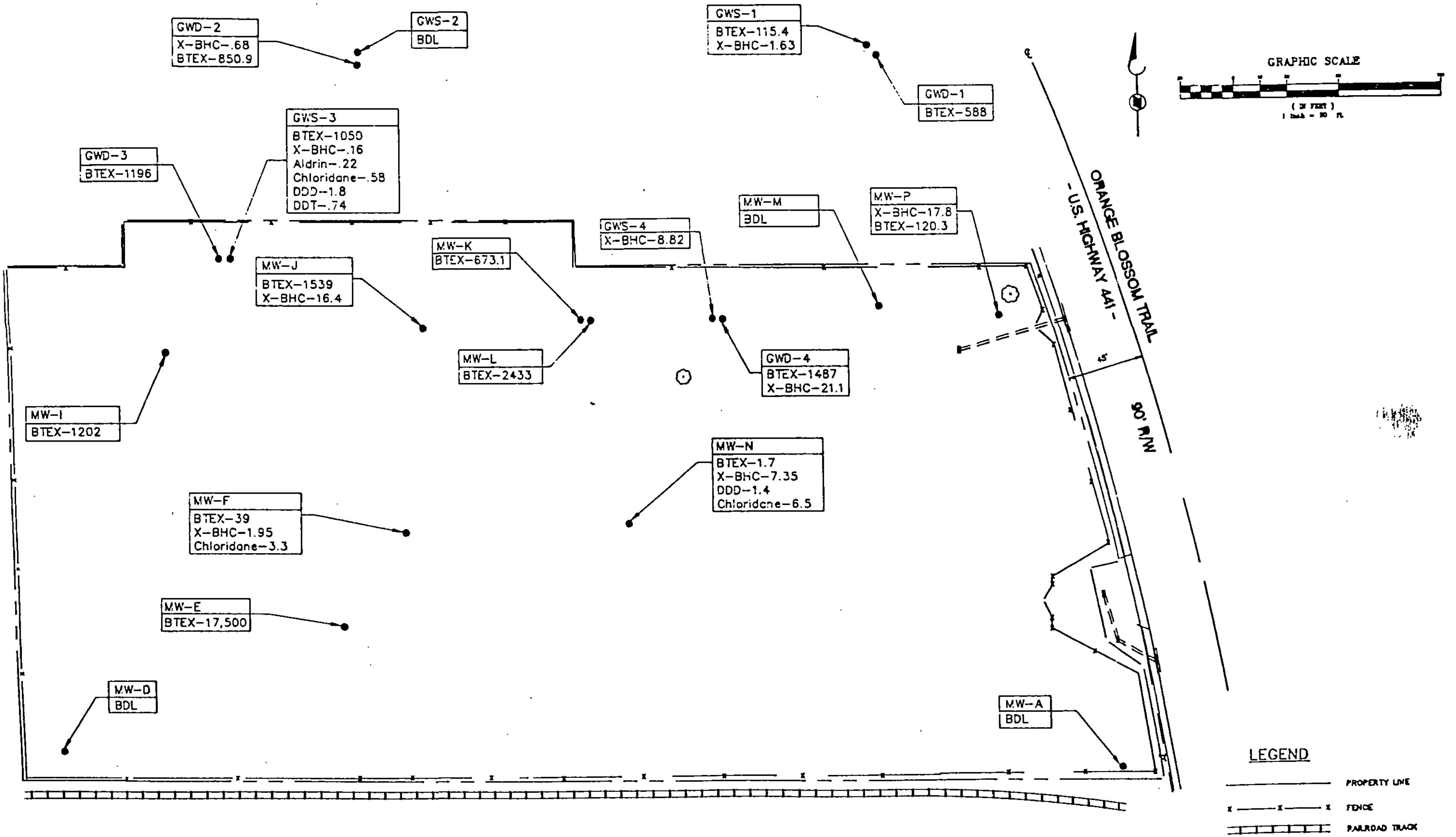
Figure 5-10
Results of Groundwater Analysis
September, 1990



NOTES:
1) X-BHC = SUM OF ALL ISOMERS OF LINDANE DETECTED
2) BTEX-SUM OF BENZENE, TOLUENE, ETHYLBENZENE AND XYLENE
3) BDL-ALL ANALYTES BELOW DETECTION LIMITS
4) ALL UNITS IN UG/L

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Figure 5-11
Results of Groundwater Analysis
October 1991

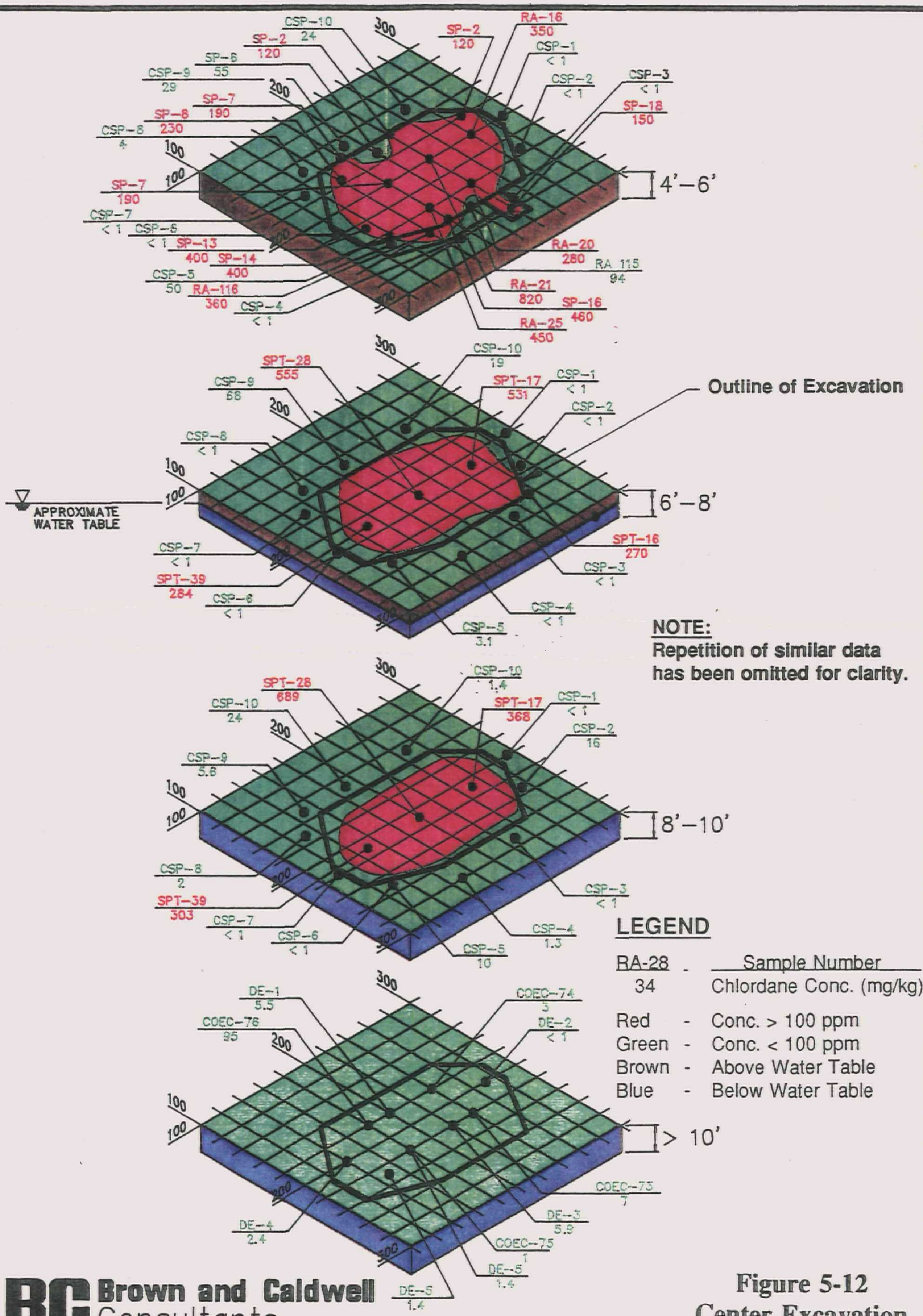

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Figure 5-12
Center Excavation Source Removal

APPENDIX J

HYDRAULIC CONDUCTIVITY TEST RESULTS

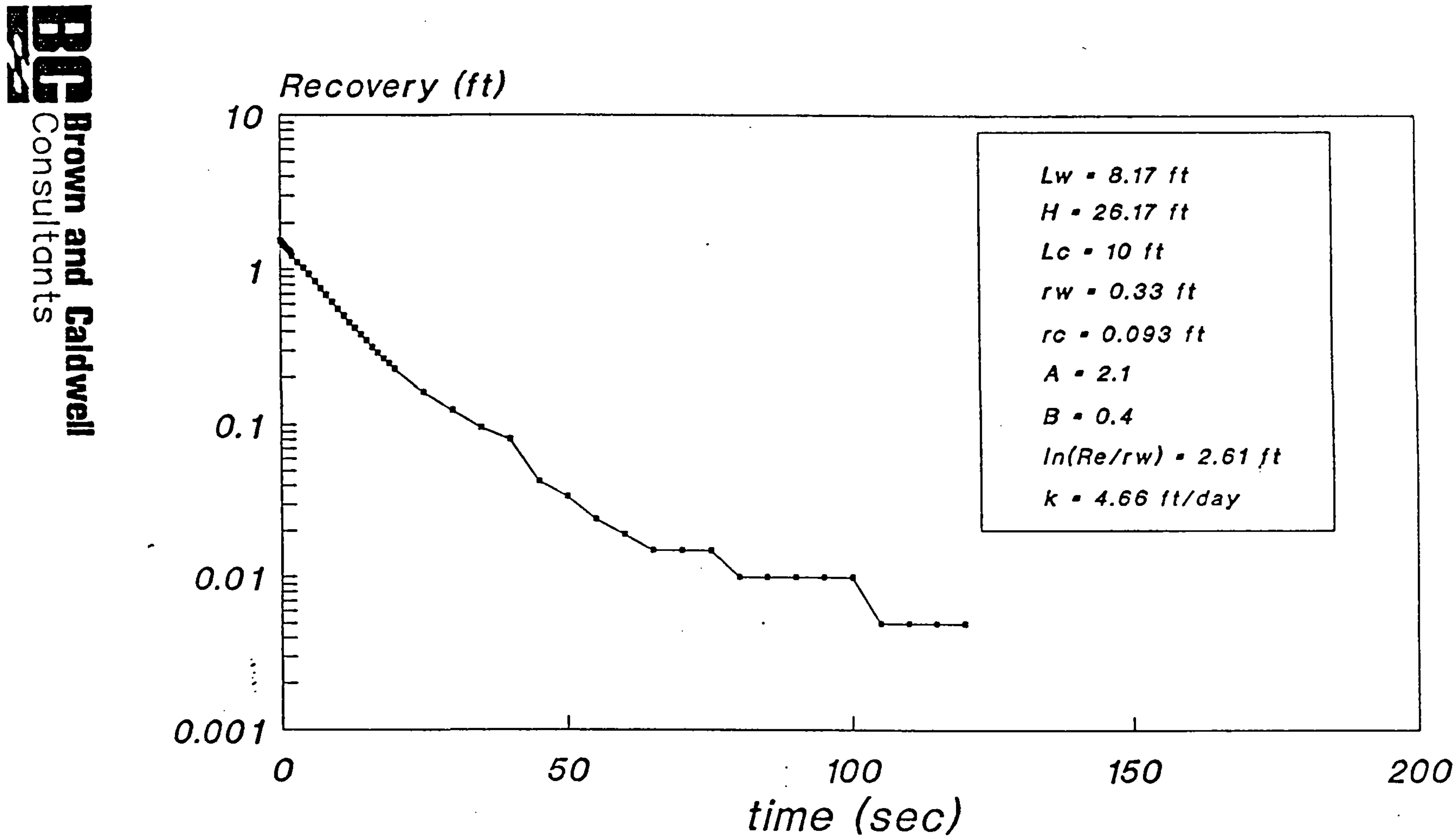

Figure J-1
Hydraulic Conductivity
Test Results
Monitor Well GWS-1

2

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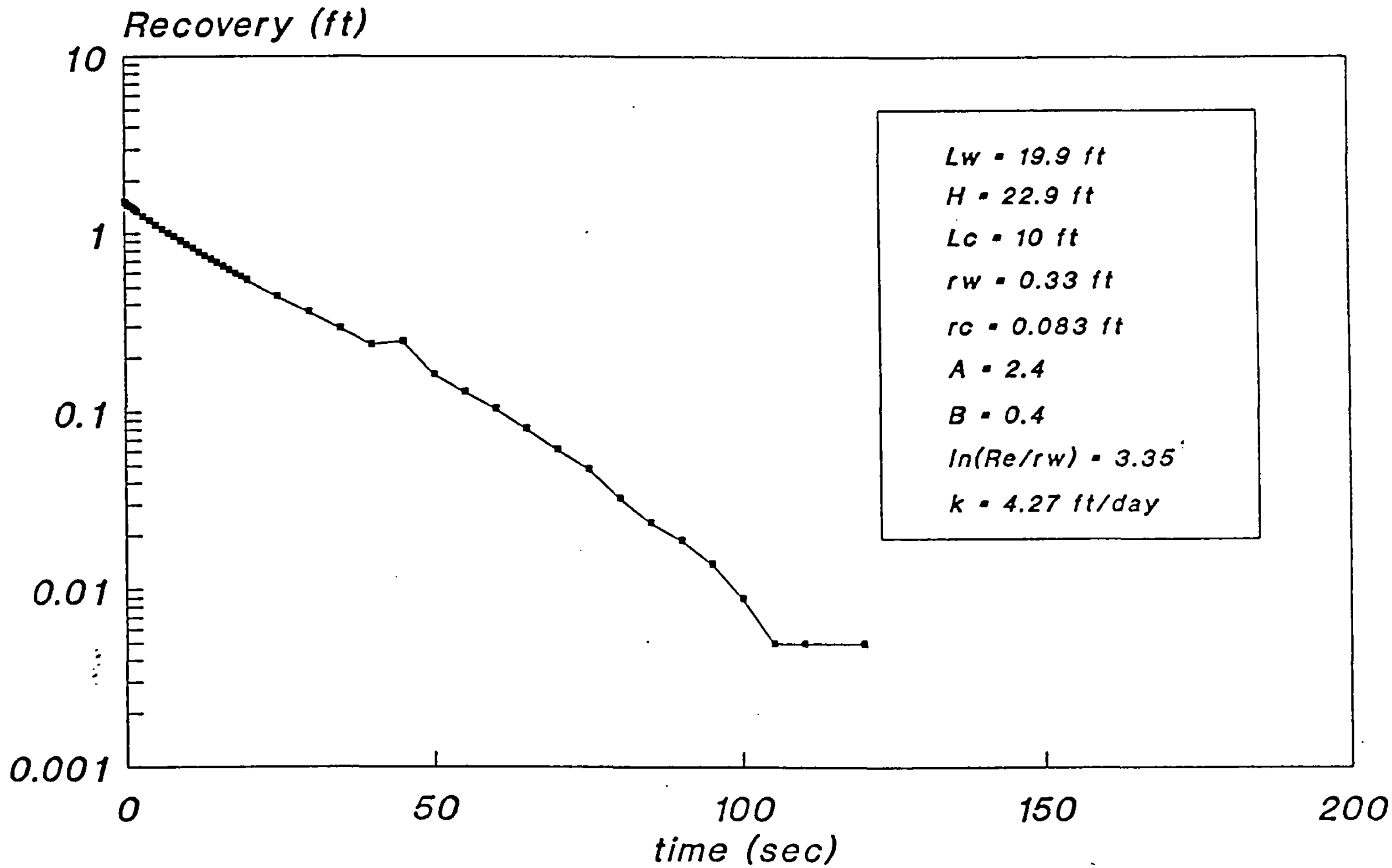

Figure J-2
Hydraulic Conductivity
Test Results
Monitor Well GWD-1

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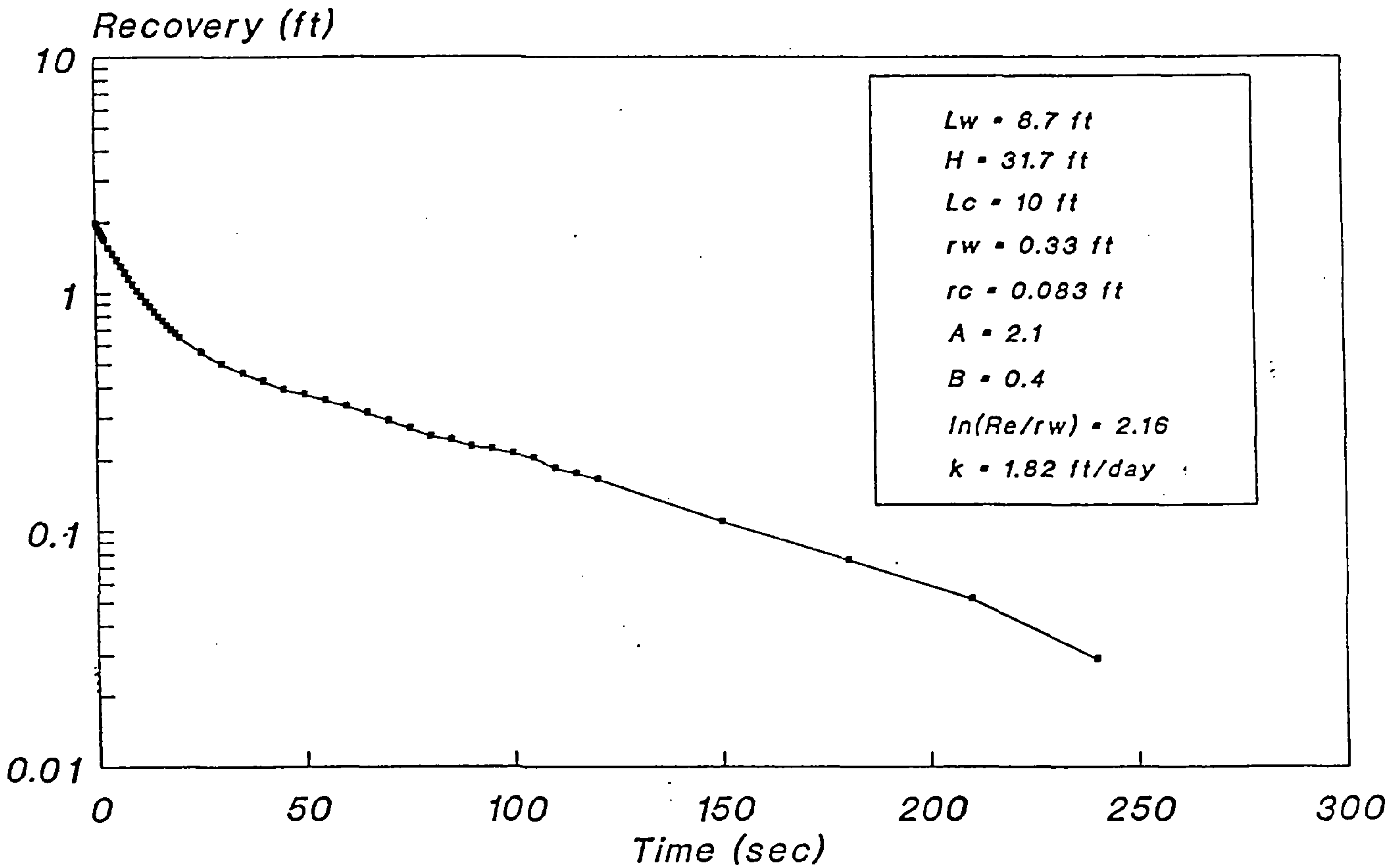

Figure J-3
Hydraulic Conductivity
Test Results
Monitor Well GWS-2

4

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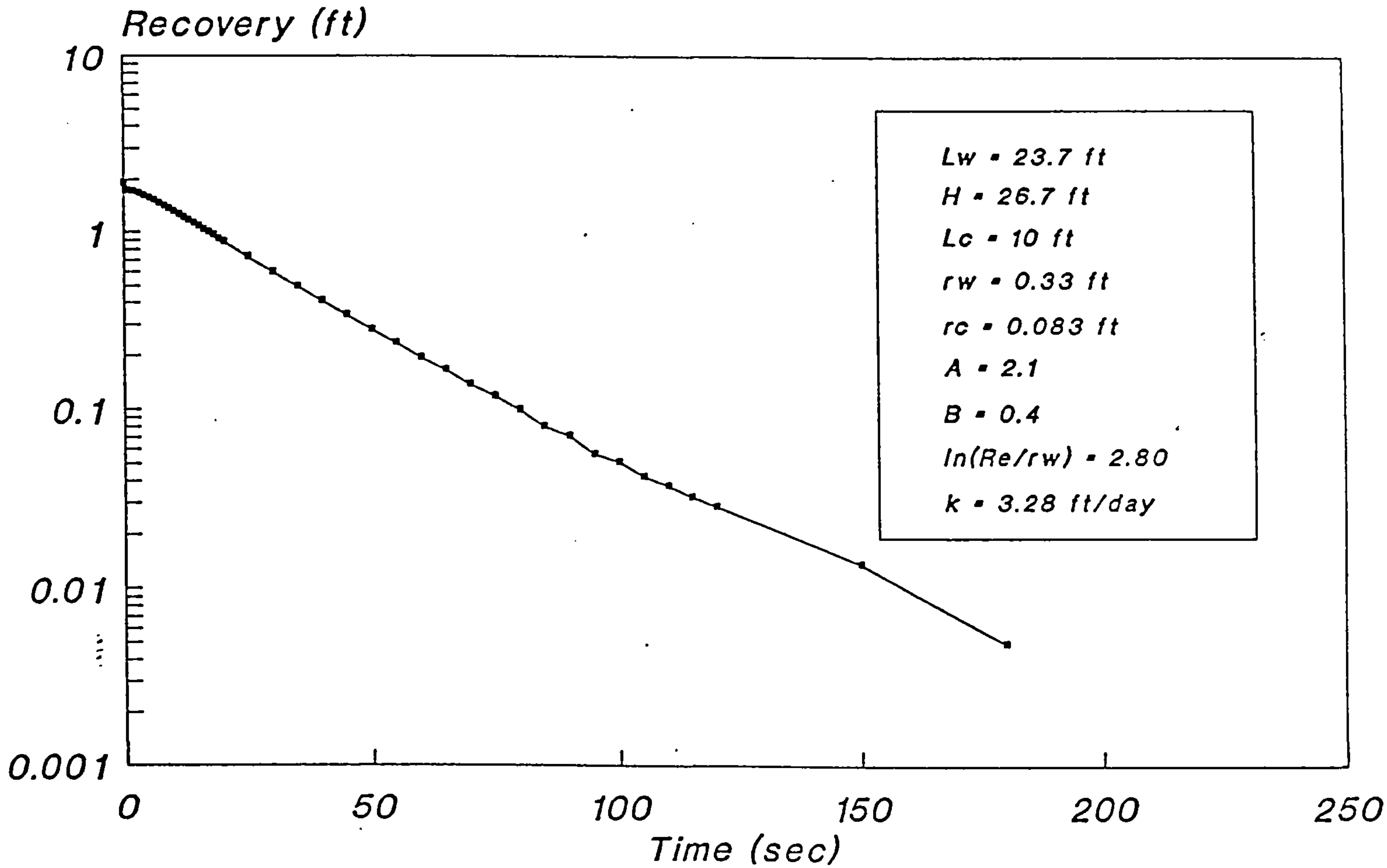

Figure J-4
Hydraulic Conductivity
Test Results
Monitor Well GWD-2

5

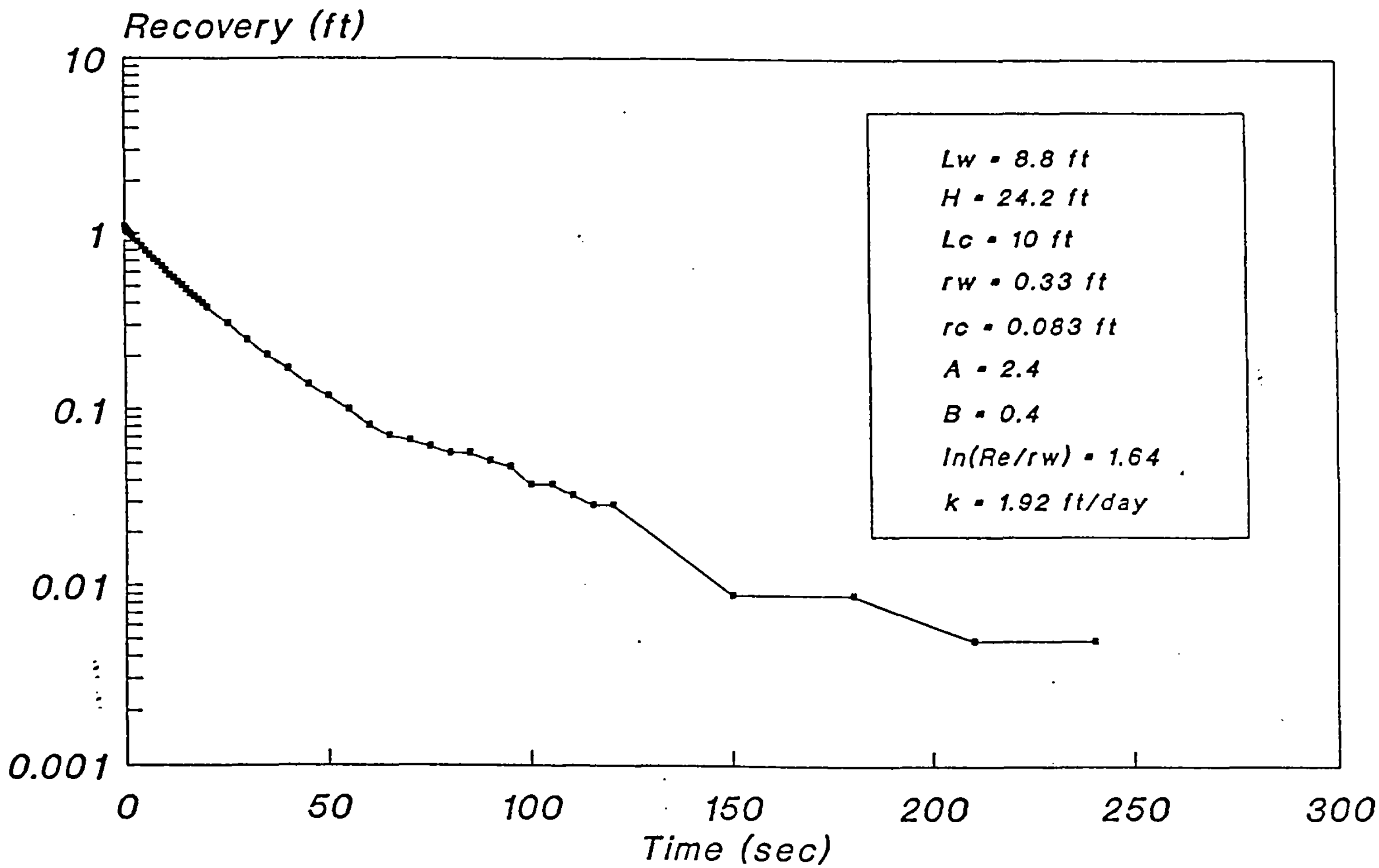

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Figure J-5
Hydraulic Conductivity
Test Results
Monitor Well GWS-4

6

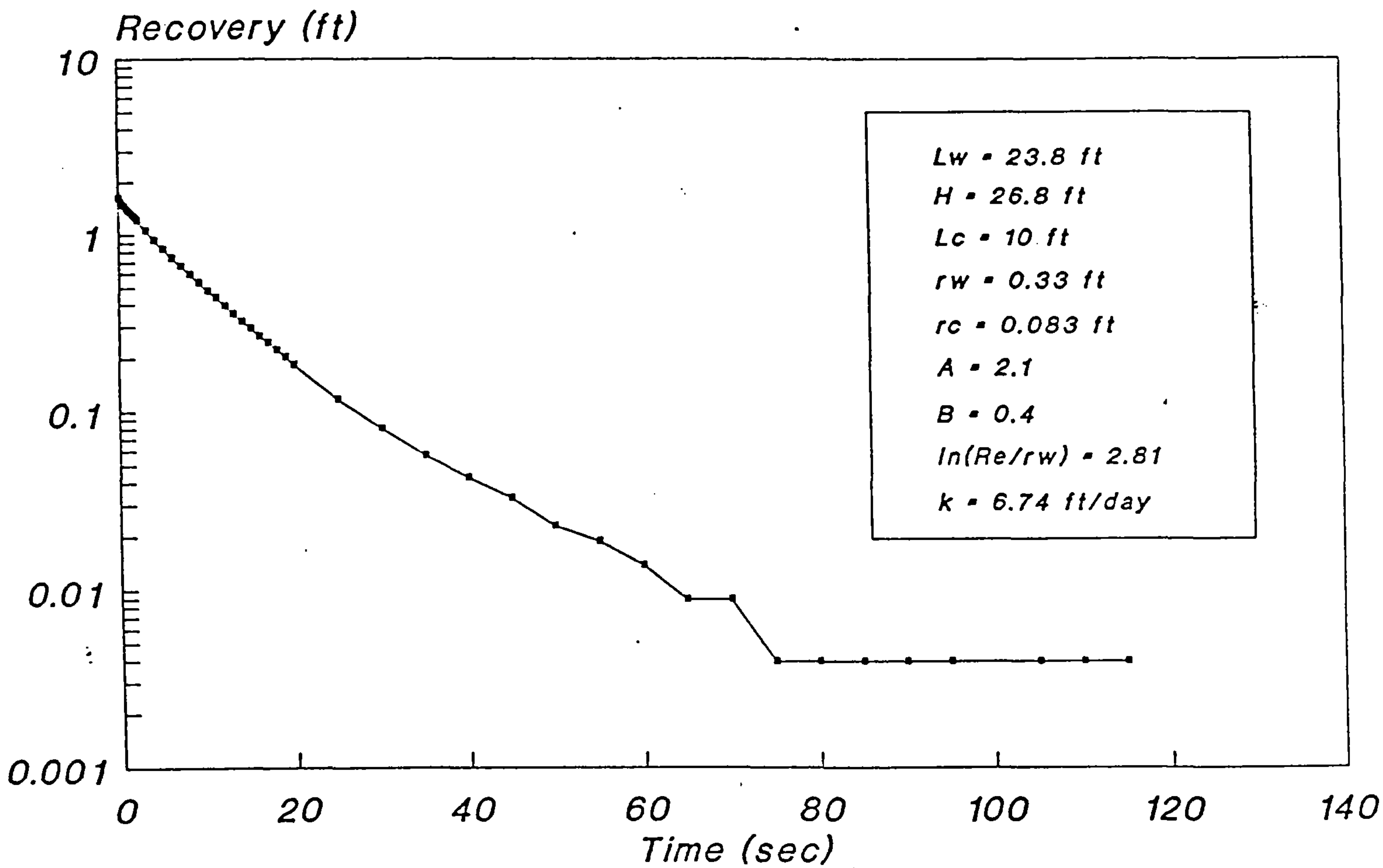

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Figure J-6
Hydraulic Conductivity
Test Results
Monitor Well GWD-4

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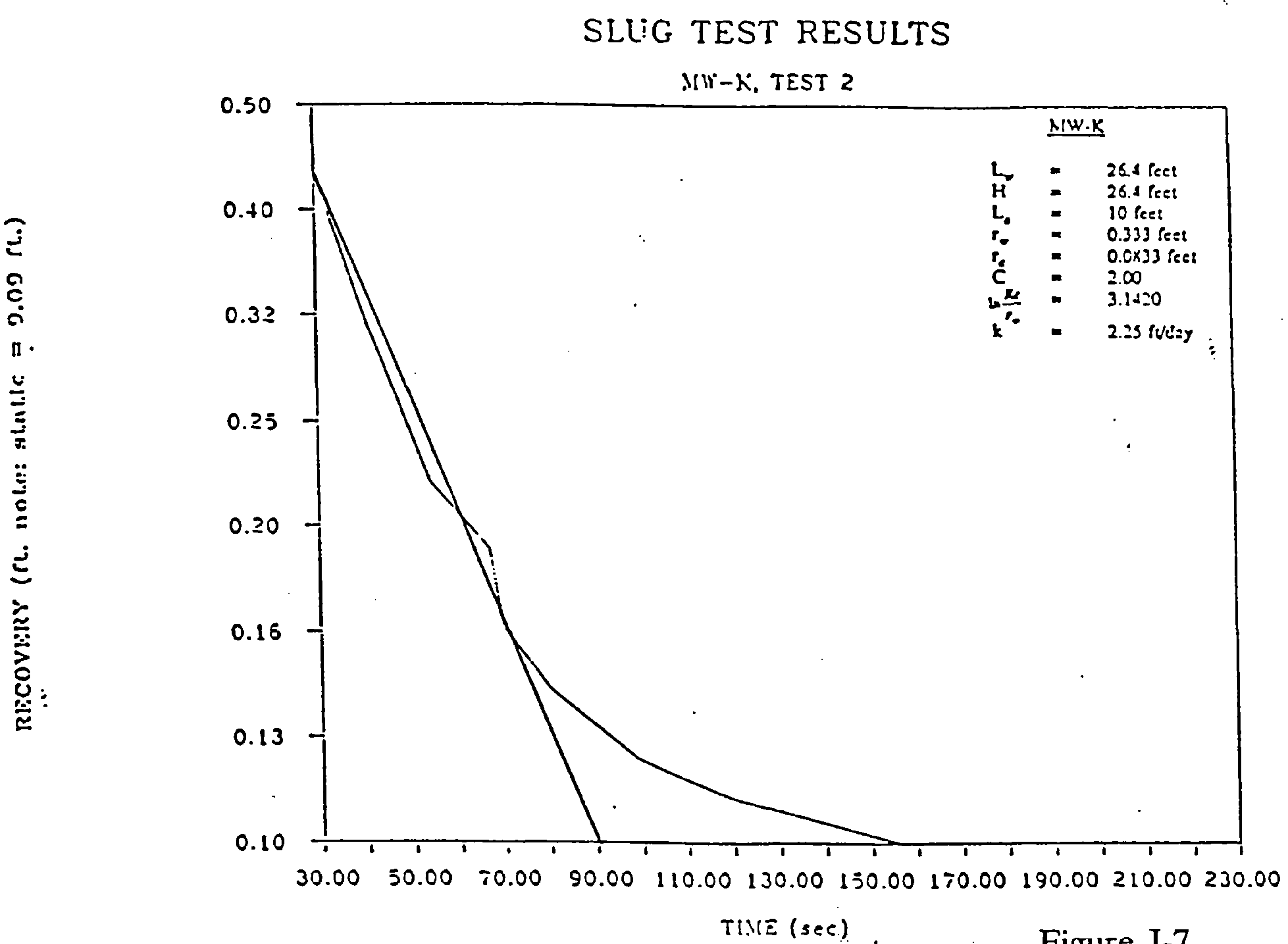

Figure J-7
Hydraulic Conductivity
Test Results
Monitor Well K

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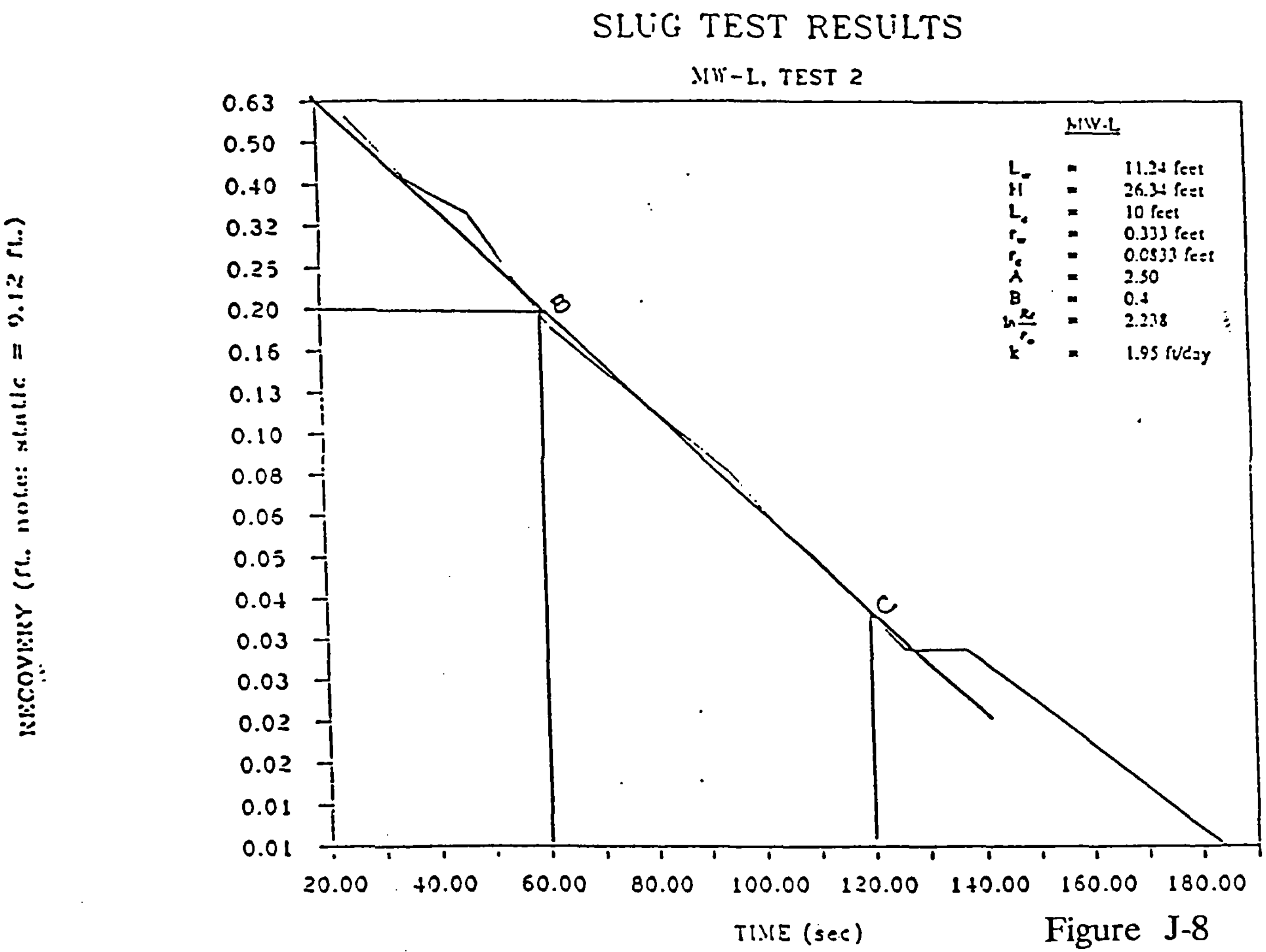

Figure J-8
Hydraulic Conductivity
Test Results
Monitor Well L

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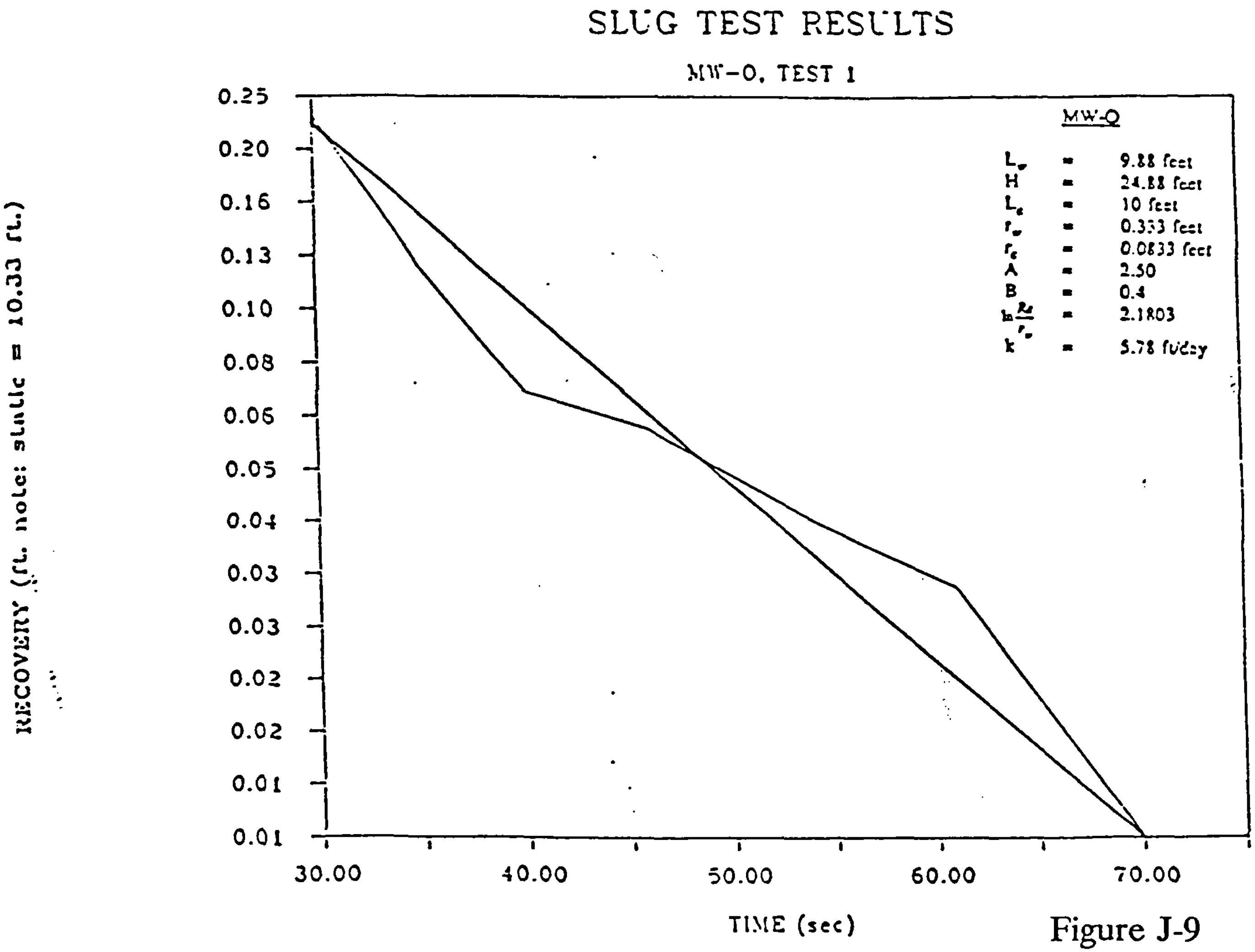

Figure J-9
Hydraulic Conductivity
Test Results
Monitor Well O

REFERENCE 31

United States Department of the Interior

GEOLOGICAL SURVEY

WATER RESOURCES DIVISION
224 West Central Parkway, Suite 1006
Altamonte Springs, Florida 32714
(407) 648-6191

August 19, 1993

Cynthia Gurley
Site Assessment Manager
U.S. Environmental Protection Agency
Region 4
345 Courtland Street, N.E.
Atlanta, GA 30365

Dear Ms. Gurley:

I recently sent you copies of my work maps of the plotted locations of all drainage wells on the Orlando East and Orlando West topo quads. I omitted an explanation of the well descriptions in my previous letter.

Drainage wells in the Orlando area are class V and usually tap the Upper Floridan aquifer. The wells range in diameter from 6 to 30 inches, and range in depth from 150 to 1,000 feet. Because the potentiometric surface of the Upper Floridan aquifer is about 50 feet below land surface in the area, water from the land surface and the surficial aquifer system can enter the lower aquifer by gravity fall through the wells. These wells are direct connections from the land surface to the Upper Floridan aquifer, typically receiving stormwater or lake overflow. They were installed to short circuit the natural seepage from the surficial aquifer system through the semi-confining unit of clayey sand to the Upper Floridan aquifer.

Emerald Sink is the only known open sinkhole in your area of study. The sinkhole apparently is directly connected to the Upper Floridan aquifer, allowing surface water drainage and seepage from the surficial aquifer system to short circuit the semi-confining unit of clayey sand. The water level in the sink reflects the potentiometric surface of the Upper Floridan aquifer.

If you need more information , please call me at 407-648-6191.

Sincerely,

Anne Bradner

Anne Bradner
Hydrologist

Table 2. *Summary of geologic and hydrogeologic units and their water-bearing characteristics in and description of the geologic*

[>, greater than]

Series	Geologic unit	Thickness (feet)	Lithology	Water-bearing characteristics	Hydrogeologic unit
Holocene to Pliocene	Undifferentiated; may include Caloosahatchee Marl	0-100	Quartz sand with varying amounts of clay and shell.	Varies widely in quantity and quality of water produced.	SURFICIAL AQUIFER SYSTEM
Miocene	Hawthorn Formation	100-150	Gray-green, clayey, quartz sand and silt; phosphatic sand; and buff, impure, phosphatic limestone.	Generally low permeability except for limestone, shell, or gravel beds. Lower limestone beds may be part of Upper Floridan aquifer.	INTERMEDIATE CONFINING UNIT
					FLORIDAN AQUIFER SYSTEM
Eocene	Ocala Limestone	0-125	Cream to tan, fine, soft to medium hard, granular, porous, sometimes dolomitic limestone.	Moderately high transmissivity. Most wells also penetrate underlying formations.	Upper Floridan aquifer
	Avon Park Formation	>1,500	Upper section mostly cream to tan, granular, porous limestone. Lower section mostly dense, hard, brown, crystalline, fractured dolomite alternating with chalky fossiliferous layers of limestone.	Overall transmissivity very high. Contains many interconnected solution cavities. Many large capacity wells draw water from this formation.	Upper Floridan aquifer Middle semi-confining unit Lower Floridan aquifer

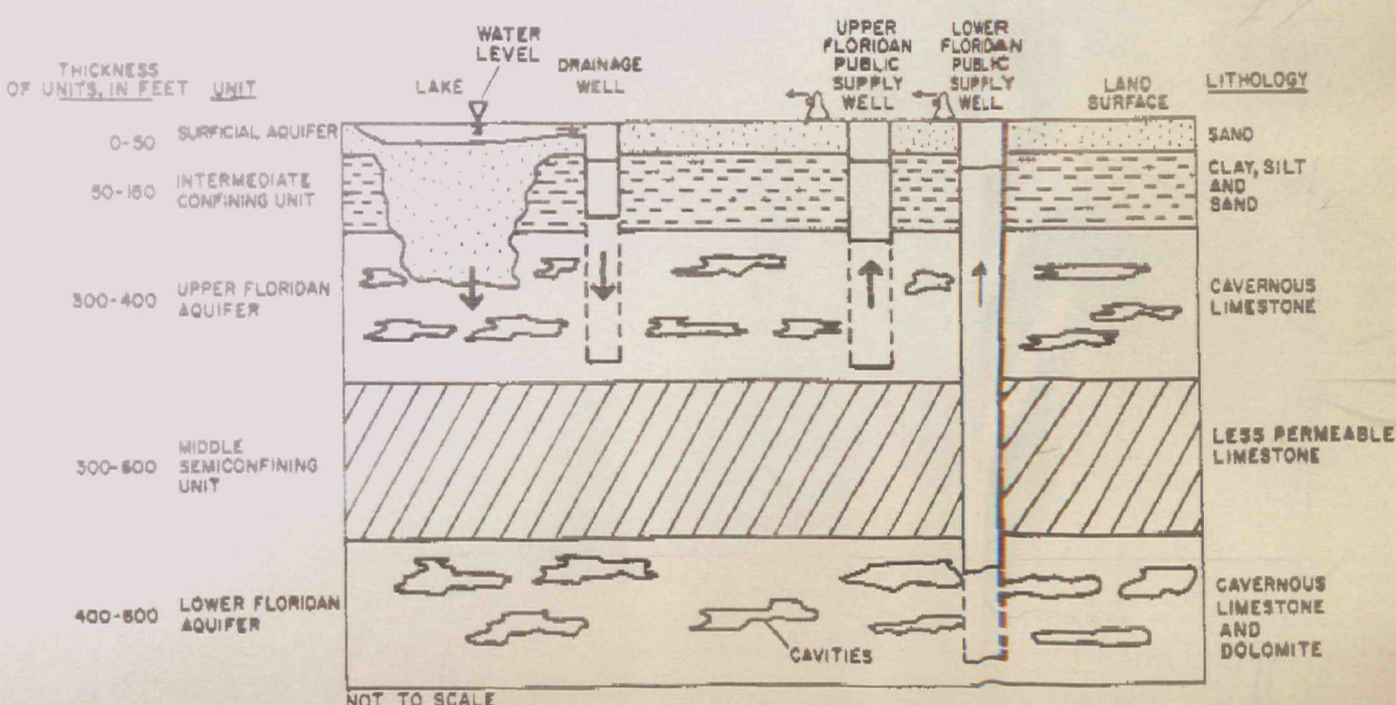

Figure 4. Generalized hydrogeologic section in the Orlando area.